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FOOD

SELECTION

and

PREPARATION

HOME ECONOMICS SERIES

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FOOD SELECTION and PREPARATION

FOURTH EDITION

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Avoide your Bokes written of Receipts,
For all such Receipts are full of Deceipts;
Trust not such Receipts, and lerne well this Clause,
Nothing is wrought but by his proper Cause:
Wherefore that Practice falleth farr behinde
Wher Knowledge of the cause is not in Minde:
Therefor remember ever more wisely,
That you woorke nothing but you knowe howe and whie.

Thomas Norton in *The Ordinall of Alchimy*

PREFACE

To the Fourth Edition

Since the end of World War II, the trend of the American food market in the direction of offering both an ever-widening variety of foods and more foods in a completely or partially ready-to-eat form has been resumed. The problem of the consumer-buyer and user is thus increasingly one of selection. It seems to the authors more pertinent than ever to introduce students to the study of foods and nutrition by a course based on the scientific findings as they relate to selection at the market as well as to the effects of various forms of household processing.

Consequently, in the Fourth Edition the book again begins with an explanation of the basic standards involved in the appraisal of foods. The organization has been changed, however, to include a first section covering all the general information on this topic, both as it applies to the individual foods and to the combinations which are included in the day's or week's meals. This is followed by a second section consisting of two chapters on the methods of processing foods. The third section takes up the structure of food materials and its general relation to the changes involved in preparation for eating. A fourth and final section consists of chapters devoted to the selection and preparation of foods following the classification used in the Bureau of Human Nutrition and Home Economics' food plans.

The subject matter continues to be planned to accompany laboratory work on food selection and preparation and on meal planning. The level of treatment of the technical aspects of food preparation requires elementary knowledge of organic chemistry. However, we use the book selectively in first courses, where the emphasis is on food selection and the laboratory is centered around the planning and preparation of family meals, with students who have had no chemistry. The more technical material is reserved for advanced students who have had the chemistry mentioned above. The summaries at the ends of the chapters in Section IV facilitate such use.

Since the writing of the first edition, little more than two decades ago, the literature in the field of food selection and preparation has expanded to the point where coverage in a single volume is impossible. We recognize that we have neither listed nor consulted all important published sources, but we have intended to credit newer findings to their authors and to list readily available papers that may serve as an introduction to further study.

The American Home Economics Association, the American Medical Association, the editors of the *Journal of Home Economics*, the *Journal of the American Dietetic Association*, and *Food Research*, and others as acknowledged in the text, have contributed to the completeness of the book by kindly permitting the use of copyrighted material. Special appreciation is also due Dr. M. J. Babcock of the New Jersey Agricultural Experiment Station, to the Bureau of Human Nutrition and Home Economics, and to the National Livestock and Meat Board for the privilege of using data or cuts as noted.

We are also deeply indebted to Dr. Marion Pfund of Cornell University for making available to us her detailed criticisms of the third edition and much of the manuscript of this edition. Our colleague, Mary Ella Snyder, read portions of the manuscript and helped clarify the presentation. Dorothy McDonald, reference librarian at the University of Maine, gave patient and untiring assistance in the location and checking of references.

MARION DEYOE SWEETMAN
INGEBORG MACKELLAR

Orono, Maine
January, 1954

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SECTION I

THE APPRAISAL OF FOODS

Introduction

The Roles of Food

Food in relation to health.
  Types of evidence that health is affected by food.
  General conclusions from the evidence.
Factors beside food which affect health.
The appraisal of foods.

Food plays many roles in our lives. We eat because we are hungry—perhaps in this country more often to keep from getting hungry, because it is time to eat. We eat, whether we need food or not, to satisfy our appetite for particular foods. We may even eat to compensate unconsciously for lack of affection or desired recognition from our fellows.

What we eat is influenced not only by what is available but also by our acquired likes and dislikes, by our beliefs about the healthfulness, or even a variety of magical powers, of particular foods. What we eat may even be influenced by our use of food to display wealth, or to magnify prestige, or to demonstrate sophistication. Our choices may also conform to customs—ceremonial, racial, religious, national, and familial.

FOOD IN RELATION TO HEALTH

Among all the satisfactions that influence our selection of food, the maintenance of optimum health probably brings the most enduring values. In the modern world, health is one of the foremost standards by which we rate the cultural status of a people. We are coming generally to recognize that health is an asset with which every child has a right to be endowed, so far as it is within the power of his parents and the community to provide it. We believe that the preservation of his health is a duty which every adult owes to himself and to society.

By *health* we no longer mean the mere absence of illness, which is passive health, but a state of physical vigor and mental alertness which has been well named positive or buoyant health. It is measured not only by greater average length of life but by prolongation of the characteristics of youth and postponement of the signs of old age. Such health means achievement of one's maximum capacity to do physical and mental work, to resist fatigue and disease, and to enjoy life. It brings the average person more effective and satisfying living. It rewards not only the possessor but also the community, for lack of health is the cause of important social and economic problems.

Types of Evidence That Health Is Affected by Food

Two major types of investigations indicate that health requires having the right amounts and kinds of food. One type is the *survey*, in which existing eating habits of a group are studied in relation to any signs and symptoms of nutritional deficiency discovered in physical examinations of the individuals in the group. For example, at the Forsythe Dental Infirmary in Boston, a survey was made in which diet at different times of life was related to the condition of the teeth. Two groups of children were compared: Group I had a remarkably low amount of decay, only 8 per cent of the teeth being affected; Group II had extensive decay, 60 per cent of the teeth showing such damage. Group I was found to have had decidedly more adequate diets in infancy as well as at the time of the survey, and their mothers ate better during pregnancy.[1]

Another very significant survey of this type also took place in Boston in which the condition of babies at birth was related to the quality of the mother's diet during pregnancy. When the mothers had good or excellent diets during pregnancy, 42 per cent of the infants were rated "superior" (no physical count checked against them), 45 per cent as having one physical count against them (largely minor), 10 per cent as having two physical counts against them, and 3 per cent as having congenital defects. When the mothers had poor or very poor diets only 2.5 per cent of their babies were rated "superior," another 2.5 per cent had one physical count against them, 25 per cent were fair or poor in general condition, and 67 per cent were labeled "poorest" and included those who were

[1] Sognnaes and White, *Am. J. Diseases Children,* 60: 283 (1940).

stillborn, died within 3 days of birth, had congenital defects, or were premature or "functionally premature." The poor-diet group of mothers also had more cases of toxemia during pregnancy and more difficult deliveries.[2]

The other type of evidence of the relation of food to health is that from planned experiments. An experiment differs from a survey in being a manipulated and controlled comparison of the effects of one factor at a time rather than simply an attempt to find relationships among existing factors. Much of the science of nutrition is based upon experiments with other animals. Fortunately their food requirements have commonly proved to be similar to those of man, and, in addition to the practical advantage of easier control of their food supply, they offer the scientist the opportunity of observing lifetime effects in a relatively short time.

For example, the rat, which is one of the most important laboratory animals for nutrition experiments, is at 3 years of age the equivalent of a man of 90 years. Another reason why animals have been better adapted to nutrition experiments than man himself is that they can eat, retain, and digest purified substances which nauseate humans. Also, the smaller types eat much less food than man and thus reduce the cost of experiments. Finally, animals, especially during growth period, can be used for types of experiments which should not be employed, especially with children, on account of possible permanent damage.

More recently, however, a wider range of nutrition experiments with human subjects has proved particularly valuable in showing the effects of food, because there can be no question of species differences.

In one type of nutrition experiment on humans, part of the group is left on its ordinary diet while the rest are given supplementary foods of superior nutritional value. For example, in one such experiment, 400 pregnant women with low incomes were divided into three groups, one allowed to continue its poor diet, another either already on a good diet or having sufficient financial resources to obtain one when given the required information, and a third which was given such supplementary foods as milk, cheese, eggs, oranges, and canned tomatoes. Throughout pregnancy, the mothers in the two good-diet groups had better health and fewer compli-

[2] Burke et al., *J. Nutrition*, 26: 569 (1943).

cations than the mothers left on poor diets. The poor-diet mothers had many more miscarriages, stillbirths, and premature births. The advantages of the good diets affected the babies themselves—those born to the good-diet mothers having much less illness during the first six months of life according to the records kept, and no deaths, whereas there were three deaths among the babies of the poor-diet mothers.[3]

A second kind of nutrition experiment, the curative type, is employed with groups who show a suspected sign of nutritional deficiency. For example, when a group of school children in northern Maine whose diets contained few foods of high ascorbic acid potency were found to have low blood values for this vitamin, it was suspected that the many cases of swollen, inflamed gums were a sign of mild scurvy caused by this dietary lack. Forty-one children with this condition were given 200 milligrams of ascorbic acid in pill form daily for 3 weeks. No change was made in their food during this time. In this short period, about two-thirds of the group showed some degree of improvement, 13 becoming free from inflammation. Probably, most of the others would have been cured with longer treatment, though there are other recognized causes of this condition. It was concluded that many cases of inflamed gums in children are caused by a dietary deficiency of ascorbic acid.[4]

A third type of nutrition experiment may be called the induced deficiency. The most exact experiments of this type use diets made up of purified nutrients so that the effect of a single deficiency can be studied. Providing purified nutrients in the amounts that humans eat is very expensive and gives a mixture very difficult for them to eat and retain. In recent years, improved methods of chemical analysis have made it possible to surmount this difficulty by using combinations of ordinary foods selected to be extremely deficient in one nutritive essential at a time. Though such food combinations are almost always deficient in other essentials also, we can now balance them with purified drugstore forms, so that the net result is a diet which the subject can eat and digest in sufficient quantity to meet his needs for all but one known essential.

An excellent example of an induced-nutritional-deficiency experiment was carried out at the Mayo Clinic in Rochester, Minnesota. Normal women were given meals containing about one-tenth

[3] Ebbs et al., *J. Nutrition*, 22: 515 (1941).

[4] Crane and Woods, *New Eng. J. Medicine*, 224: 503 (1941).

of the *Recommended Allowance* * of thiamine. The foods were white flour, sugar, tapioca, cornstarch, washed polished rice, white raisins, egg white, cottage cheese, butter, fat, black tea, and cocoa. These were supplemented with drugstore sources of riboflavin, niacin, ascorbic acid, vitamins A and D, iron, and calcium. By the end of the 88 days, all the subjects showed the following symptoms: depressed mental states, generalized weakness, dizziness, backache, soreness of muscles, loss of appetite, and nausea. Belief that these symptoms were caused by the lack of thiamine was substantiated by their disappearance when thiamine was given, though the food and supplements remained unchanged.[5]

General Conclusions from the Evidence

Large numbers of such surveys and nutrition experiments have demonstrated that we require definite amounts of certain food components for normal growth and health. They have proved that eating the wrong kinds of food causes not only specific diseases but vague "subcritical" symptoms associated with poor health, lowered efficiency, and diminished resistance to fatigue and disease. This is but the negative side of our knowledge. More important is the evidence that eating the right kinds and amounts of food may help most of us to attain a degree of health and vigor relatively rare among us now.

Dr. Henry C. Sherman of Columbia University has demonstrated with a colony of rats that a food supply which is adequate for normal reproduction and longevity through many generations can still be improved. When certain nutrients, especially vitamin A, riboflavin, and calcium, are added in even larger amounts, the animals mature earlier on the average, live longer, and begin to show signs of old age later. The extra life is not added to the period of declining vigor but to the period of the prime. Since about 1940 results of improving the diets of aging humans have given us hope that our lives may be lived on a higher plane of health and vitality with but a brief period of breakdown leading to death at the end.

* The term *Recommended Allowance* is used to refer to the amount of a nutrient recommended for daily consumption by the Food Nutrition Board of the National Research Council.

[5] Williams et al., *Arch. Internal Med.*, 66:785 (1940).

FACTORS BESIDE FOOD WHICH AFFECT HEALTH

Food is only one of the environmental factors affecting health—others include medical knowledge and care, exposure to infectious diseases, occupational and traffic hazards, sanitation, habits of hygiene, housing, climate, leisure, and emotional stress. Good food choices alone can not assure optimum health if any of these factors is unfavorable. The nutritionist joins with other workers in the health sciences in recognizing the interrelationship of all these factors. But probably it is safe to say that, in our country, more people have it within their power to improve their health by changing their habits of eating than in any other way.

THE APPRAISAL OF FOODS

In this book, we shall examine the findings of nutritional science with the purpose of showing practical applications in making individual choices, and in planning and preparing family meals which will give maximum contributions of both health and pleasure at differing levels of expenditure of money and labor. Altogether, five yardsticks enter into the appraisal of relative values of foods in terms of the major roles they play. The first three evaluate the health-giving capacity of a food and may be designated as (1) nutritive quality, (2) digestibility, and (3) sanitary quality. The others are (4) palatability or appetite appeal, and (5) economy, which covers relative cost in both labor and money. The first five chapters of this book are concerned with an analysis of these measures of the value of foods and the general roles they should play in intelligent food selection and meal planning. The remaining chapters of the book deal with applications of the yardsticks to particular foods in their natural state and after processing or preparation.

CHAPTER 1

NUTRITIVE QUALITY IN THE APPRAISAL OF FOODS

The food needs of the human body.
  The need for tissue building and repair.
  The need for energy.
  The need for regulating substances.
How foods meet the needs of the body.
Nutritional status in the United States.
Planning for good nutrition in the day's meals.

Scientific food selection and preparation are based on an understanding of our nutritional needs. Fortunately, from the progress already made in the study of nutrition we can learn enough about the needs of the body to choose adequate meals. We speak of the capacity of a food to contribute to the various requirements of the body as its *nutritive quality*.

THE FOOD NEEDS OF THE HUMAN BODY

The food needs of the human body have been summarized as follows:

1. The need for nutrients to build and repair tissue.
2. The need for nutrients to yield energy for heat, activity, and a surplus to provide for an appropriate store.
3. The need for nutrients to regulate body processes.

The Need for Tissue Building and Repair

A human being develops from an egg too small to be seen by the naked eye. Even after growth is completed, food must be utilized to repair worn-out, depleted tissues. Since the body is composed largely of proteins, ash constituents, and water, these are the components of food materials which function in producing new and in repairing old tissues.

Proteins are composed of the elements carbon, hydrogen, nitrogen, oxygen, sulfur, and phosphorus. These elements are combined to form twenty-one *amino acids,* a number of which are joined together in various combinations to make different kinds of protein molecules. During digestion the protein is hydrolyzed, and the resulting amino acids are absorbed. Besides water, proteins are the main constituents of protoplasm; they consequently occur in all animal or plant tissue. Lean meat, fish, poultry, eggs, and cheese contain especially large percentages of protein.

Not all proteins are of equal value in building and repairing tissues, because they differ in their content of amino acids; at least ten amino acids are probably essential because we cannot synthesize them at all or in sufficient quantities to meet our needs.* The amino acid requirements for growth of new tissue seem to be more rigid than those for maintenance of tissue already constructed. When proteins contain amino acids adequate in kind for growth, they are called *complete proteins;* when adequate for maintenance only, *partially complete;* and when inadequate for both, *incomplete.* According to this classification, milk proteins are complete, some cereal proteins are partially complete, and gelatin is incomplete.

Protein requirements for human beings are estimated in grams per day; they vary primarily with age and size. See Table I for *Recommended Allowances.* When more protein is consumed than is required for building and repair, it is burned to furnish energy or stored in the form of fat or glycogen (a carbohydrate). *Recommended Allowances* provide for a surplus in order to ensure adequate amounts of each amino acid. If children fail to obtain enough of the right kind of amino acids in their foods, their growth is stunted and their muscle development is subnormal. Adults under these circumstances suffer from muscle weakness and wasting, and also anemia. There is no conclusive evidence that large surpluses of protein are harmful to the normal body.

The human body contains more calcium than any other mineral. About 99 per cent of it is present in bones and teeth, but the remaining 1 per cent, which is in the blood and soft tissues, has extremely important regulating functions. Phosphorus is found together with calcium in the bones and teeth, but it is also present

* Ten amino acids have been proved to be essential for rat growth, but it has not been considered wise to experiment in the same way with children. Adult men, however, have been able to maintain their body protein on a mixture of eight.

Table I. Recommended daily dietary allowances *

Family members	Food energy, calories	Protein, grams	Calcium, grams	Iron, milligrams	Vitamin A, I.U.	Thiamine, milligrams	Riboflavin, milligrams	Niacin, milligrams	Ascorbic acid, milligrams	Vitamin D, I.U.
Children up to 12 years										
Under 1 year	†	‡	1.0	6	1500	0.4	0.6	4	30	400
1–3 years (27 pounds)	1200	40	1.0	7	2000	.6	.9	6	35	400
4–6 years (42 pounds)	1600	50	1.0	8	2500	.8	1.2	8	50	400
7–9 years (58 pounds)	2000	60	1.0	10	3500	1.0	1.5	10	60	400
10–12 years (78 pounds)	2500	70	1.2	12	4500	1.2	1.8	12	75	400
Girls										
13–15 years (108 pounds)	2600	80	1.3	15	5000	1.3	2.0	13	80	400
16–20 years (122 pounds)	2400	75	1.0	15	5000	1.2	1.8	12	80	400
Boys										
13–15 years (108 pounds)	3200	85	1.4	15	5000	1.5	2.0	15	90	400
16–20 years (144 pounds)	3800	100	1.4	15	6000	1.7	2.5	17	100	400
Women (123 pounds)										
Sedentary	2000	60	1.0	12	5000	1.0	1.5	10	70	§
Moderately active	2400	60	1.0	12	5000	1.2	1.5	12	70	§
Very active	3000	60	1.0	12	5000	1.5	1.5	15	70	§
Pregnancy (latter half)	2400 ‖	85	1.5	15	6000	1.5	2.5	15	100	400
Lactation	3000	100	2.0	15	8000	1.5	3.0	15	150	400
Men (154 pounds)										
Sedentary	2400	70	1.0	12	5000	1.2	1.8	12	75	§
Physically active	3000	70	1.0	12	5000	1.5	1.8	15	75	§
With heavy work	4500	70	1.0	12	5000	1.8	1.8	18	75	§

* Source: Recommended Dietary Allowances, *National Research Council Reprint and Circular Series* 129, revised 1948. This table is a goal, subject to revision, toward which to aim in planning practical dietaries. The recommended allowances can be attained with a good variety of common foods which will also provide other minerals and vitamins for which requirements are less well known. For further recommendations and explanations, see the National Research Council's publications.

† 110 calories/2.2 pounds (1 kg.) body weight at 6 months. (Energy requirements are 120 calories/2.2 pounds in early infancy and 100 calories/2.2 pounds at 1 year.)

‡ 3.5 grams/2.2 pounds (1 kg.) body weight.

§ For persons who have no opportunity for exposure to sunshine and for elderly persons, the ingestion of small amounts of vitamin D may be desirable.

‖ The value of 2400 calories represents the allowance for pregnant sedentary women. If more active, additional calories may be needed.

in every cell, and, like calcium, has regulating as well as building functions. We need more phosphorus than calcium in our food, but phosphorus is so widely distributed that we usually get enough if we obtain sufficient calcium. Calcium is most abundant in milk; in plants it is found in largest quantity in green leaves. Phosphorus is furnished in large quantities by meat, whole cereals, and milk.

It is desirable to eat foods which give us generous supplies of calcium and phosphorus, because portions of each laid down in the bones may be withdrawn to maintain their regulative functions when the amount in food is inadequate. If children have a very low intake of calcium, their growth is stunted due to failure of the skeleton to enlarge. A lesser deficiency in either children or adults may cause the bones to be of subnormal content. Pregnant women and mothers nursing their babies require especially large amounts of calcium in their food, for, if it is not supplied by their food, it will be withdrawn from their bones, leaving them in a fragile, demineralized condition and perhaps causing nervous symptoms.

Most of the iron in the body is used in building the protein *hemoglobin*. Hemoglobin is found in muscle tissue and especially in red blood cells where it helps to carry oxygen to all parts of the body. Hemoglobin is broken down continuously, and almost all of the iron is salvaged. Persons who need the most food iron include children, women of child-bearing age, and those suffering from effects of loss of blood or past iron deficiency. See Table I for *Recommended Allowances* of iron for different types of persons.

When the amount of hemoglobin in the blood is subnormal, the condition is known as *anemia*, and the victim usually suffers from weakness and general ill health. Anemia may be caused by failure to eat foods containing a sufficient amount of iron, but it may also be caused by other factors, such as poor utilization of iron by the body or by large losses of blood. Iron is found in largest amounts in meats, especially liver, egg yolk, whole grains, dry beans, and green leaves.

Copper is now known to be needed in extremely small amounts, along with iron to build hemoglobin. However, there seems to be little danger that people who have enough iron will fail to have sufficient copper.

Iodine is essential for the production of the secretion of the thyroid gland, *thyroxin*. When the supply of this material is inadequate, a diseased condition of the thyroid known as simple goiter may develop. Sea foods or foods grown where the soil contains iodine in

sufficient quantity carry enough of this mineral to supply people who eat them in substantial amounts, but, in large areas of the United States, the only practical way to get enough is to use iodized salt. The quantity of iodine required is so small that no daily allowances are suggested.

Other minerals enter into the building of body tissues but need not be considered in choosing foods, because they are so widely distributed that one is unlikely to fail to obtain a sufficient amount. There is no danger that normal people will be affected adversely by surpluses of minerals in the amounts furnished by natural foods. Those portions which are not used or stored are readily excreted.

Because two-thirds of the body weight is water, it is evident that water is an important building material. Much is obtained as a part of foods and food mixtures, the rest in drinking water and beverages. Daily requirements vary with size, atmospheric conditions, and strenuousness of activity. Probably the sensation of thirst is usually a safe guide, but dryness of the lips and skin sometimes indicates a deficiency.

The Need for Energy

The body may be compared to an engine in that it burns fuel in developing power to do work, some forms of which must continue as long as life itself. Even when we are sleeping quietly, the activities of the heart and respiratory muscles and the maintenance of normal muscle tone demand the expenditure of energy. Furthermore, healthy human bodies are maintained at a temperature of approximately 98.6 degrees F. (37 degrees C.); the heat required for this is supplied by the combustion of energy-producing foodstuffs.

The unit of measure of heat is the *calorie*, the amount of heat required to raise the temperature of 1 gram of water 1 degree C. In measuring the fuel value of foods, the large Calorie,* which is the equivalent of one thousand times that defined above, is the unit used. The amount of heat produced by various food materials can be determined by burning them in an apparatus called a calorimeter and applying corrections for slight losses when combustion takes place in the body. The foodstuffs used for energy are carbohydrates, fat, and protein.

* As in other books on food and nutrition, the large calorie will be implied whether the word is capitalized or not.

Carbohydrates are compounds of carbon, hydrogen, and oxygen, with hydrogen and oxygen usually present in the proportion of two to one. The simplest carbohydrates contain only one sugar unit ($C_6H_{12}O_6$) in the molecule and are called *monosaccharides;* those containing two–four units, *oligosaccharides;* and those containing more than four, *polysaccharides.* During digestion, all are split to monosaccharides, which are the only carbohydrates that are finally absorbed into the blood stream. All carbohydrates yield 4 calories per gram.

Carbohydrates of importance in foods may be classified as follows:

1. Monosaccharides.
   Glucose (dextrose or grape sugar) found in fruits, honey, etc.
   Fructose (levulose or fruit sugar) found in fruits, honey, etc.
   Galactose produced by digestion of lactose.
2. Disaccharides.
   Sucrose (cane or beet sugar) hydrolyzes to form one molecule of glucose and one molecule of fructose. Found in sugar cane, sugar beets, maple sirup, fruits, etc.
   Lactose (milk sugar) hydrolyzes to form one molecule of glucose and one molecule of galactose. Found in milk.
   Maltose (malt sugar) hydrolyzes to form two molecules of glucose. Produced by partial digestion of starch and formed from starch during cooking under certain conditions.
3. Polysaccharides.
   Starch hydrolyzes to form many molecules of glucose. Found in cereals, potatoes, sweet corn, etc.
   Dextrins, products intermediate between starch and maltose which are formed during digestion and sometimes during heating. Found in corn sirup, toast, etc.
   Cellulose hydrolyzes to form glucose in the laboratory but is only slightly broken down in the human body. Found in the fibrous portion of plants.

Like carbohydrates, fats are composed of carbon, hydrogen, and oxygen, but on digestion they hydrolyze to form *fatty acids* and *glycerol.* They serve as storage material in both animal and plant tissue and are found abundantly in fat meat, butter, nuts, etc. Fats are our most concentrated energy foods, yielding 9 calories per gram.

Protein products used for energy by well-nourished persons consist of the extra amino acids not required for tissue building or repair. However, if anyone fails to obtain enough carbohydrate and

fat to go with the surplus amino acids to meet his energy requirements over a long period of time, his stores of fat will be depleted. Then protein will be used to meet energy needs instead of building and repairing tissue. This happens when persons are starving as a result of illness or for other reasons lack sufficient food. Proteins, like carbohydrates, yield 4 calories per gram.

Energy requirements depend upon height, age, and sex, and are influenced by activities, external temperatures, and some other factors. Thus tall people, young people, and males require proportionately more calories than the short, the old, and females. Mental activity does not appreciably affect energy need, but muscular activity may increase it markedly. If one faces the cold temperature of a winter day without sufficient clothing, he burns more fuel food to maintain the temperature of the body. *Recommended Allowances* for average energy needs according to age, sex, and activity are given in Table I.

The balance between energy needs and the calorie value of food consumed is the fundamental factor in the control of body weight. Calorie surpluses result in increased stores of body fat; shortages are met by depletion of these stores and loss of weight. A pound of fat represents approximately 4000 calories, but this makes more than a pound of extra body weight because of the connective tissue which supports the fat and the water which is ordinarily stored along with the fat. It has been estimated that as little as 3500 extra calories will make an extra pound of body weight except in a very obese person whose extra weight is more concentrated fat. Thus as small a surplus as 100 calories per day may result in a gain of weight of perhaps as much as 16 pounds in a year. The opposite also holds; a deficit of this amount may lead to a similar loss of weight.

Optimum weight for an individual of a given sex, height, and age depends upon the type of skeleton he has. Thus a college girl 18 years of age and 5 feet, 4 inches tall, who has broad shoulders and large bones should weigh more than another of the same age and height who has a small skeleton. Making proper skeletal measurements to be used as a basis for estimating optimum weight is so complicated that it is seldom attempted except in limited scientific investigations. In general, average weights tend to be too low for persons under 30, and probably all in this age group who are as much as 10 per cent below average for their sex, age, and height are definitely underweight. A larger margin above average, 15

to 20 per cent, should be considered within the normal range for most in this age group. Although average weights tend to rise after 30, this is not desirable for health and longevity but is merely a result of a tendency to overeat under our conditions of living.

Being overweight is undesirable because the weight and mechanical pressure exerted by the fat put excessive burdens upon the circulatory system and supporting structures, and because the digestion and metabolism of the extra food may overwork the digestive system and other organs. Being underweight is undesirable because it diminishes resistance to fatigue and infections, and because it is likely to be associated with a deficient supply of a number of food essentials.

The Need for Regulating Substances

Certain substances help maintain healthy functioning of nerves, glands, bones, teeth, muscles, and other body structures, and enable the body to use its available fuel and building materials properly. These regulating substances include water, proteins, minerals, and vitamins.

Water is the principal component of fluids which transport foods to the tissues and waste products to the organs of excretion. It dissolves electrolytes which control the functioning of nerves and other structures. When it evaporates it plays an important role in the control of body temperature. These functions serve to illustrate its importance as a regulator.

The versatile proteins, already discussed as body builders and fuels, also have regulatory functions such as control of blood volume and reaction. A large variety of minerals including calcium, phosphorus, iron, potassium, sulfur, sodium, chlorine, magnesium, copper, manganese, iodine, and cobalt, regulate a variety of body functions. Minerals help control movements of body fluids, maintain irritability of nerves, and contractility of muscles, assist with coagulation of the blood and other fluids, and facilitate the transfer of oxygen from the lungs to the tissues and carbon dioxide from the tissues to the lungs. Thus their role as regulators is also extremely important. When the calcium supply is deficient, for example, not only are the bones inadequately mineralized, but nerves and muscles may fail to function properly.

The vitamins are a group of essential nutrients which are primarily regulators. They are organic compounds otherwise unre-

lated in their chemical composition. The name was coined to fit the first of the group to be discovered (vitamin B), meaning an amine or nitrogen-containing compound essential for life. When it was later found that foods contained small amounts of other organic substances essential for life, these were also called vitamins and were differentiated by letters of the alphabet. These alphabetical designations are still used for some, but, as each vitamin is identified chemically, the tendency is to give it an appropriate chemical name which supplants the alphabetical terminology.

Since the discovery of the first vitamin the list of those identified has grown so rapidly that it is impossible to state the number generally accepted at a given time. Six are known to be especially important in human nutrition and will be the only ones discussed in this book.

Vitamin A is an alcohol ($C_{20}H_{30}O$) formed by animals from the hydrocarbons known as carotenes and a related substance called cryptoxanthin. These are yellow and orange pigments found in plants and are often designated as provitamins A. Vitamin A and the carotenes are fat-soluble. Both are present in such animal foods as egg yolk, milk, fat, and liver. Vitamin A itself is pale yellow; hence the total potency of animal products is not necessarily related to the intensity of their yellow color. The carotene content of plant materials, however, and therefore their potential vitamin A value, tends to be related to the intensity of their greenness and somewhat less closely to their yellowness. In green leaves carotenes are always present, though masked by the chlorophyll, which is green, but both increase at the same time in the growing plant. Carrots, sweet potatoes, winter squash, spinach and other greens, and apricots are excellent sources of carotenes, but the bleached inner leaves of cabbage or lettuce contain little or none. Plants do not contain true vitamin A. Both the vitamin A and the carotenes are relatively resistant to loss of potency in ordinary food processing.

Although the vitamins are primarily regulators, vitamin A functions also as a building material for a pigment in the eye known as *visual purple*. Visual purple enables us to see in dim light. A person who has failed to receive enough vitamin A may be unable to see in dim light or may develop this capacity with abnormal slowness after exposure to bright light. This condition is known as night blindness.

The important regulatory function of vitamin A is to maintain the health of epithelial tissues. These include the skin, linings of the respiratory and digestive tracts, and the outer surface of the eyes. When the supply of vitamin A is inadequate, these tissues change in structure and become somewhat dry and rough. The changes, particularly in the respiratory tract, may reduce resistance to infections such as colds, but colds have other causes and are not necessarily a sign of vitamin A deficiency. Growth and reproduction are also interfered with when vitamin A is inadequate.

Vitamin A potency is expressed in *International Units*, one such unit being the equivalent of 0.6 micrograms of beta carotene (1 milligram equals 1000 micrograms). See Table I for *Recommended Allowances.*

Thiamine (also known as vitamin B_1) is a base ($C_{12}H_{18}N_4OS$). It is a water-soluble substance widely distributed in plant and animal tissues used for food but generally in relatively low concentration. The most concentrated sources are lean pork, the bran and germ portions of grains, and dried beans and peas. Dried powdered yeast is a very rich source obtainable at drugstores and some grocery stores. Thiamine may be partly inactivated by long cooking at temperatures below boiling.

Thiamine was first known as a component of certain foods which prevented and cured the disease called *beriberi.* Beriberi has long been known in countries where polished rice is the staple cereal. The primary function of thiamine is to assist with the utilization of carbohydrates by the body. When it is deficient the nerves and other tissues fail to function properly. Symptoms of a mild deficiency include loss of appetite, impaired digestion, weakness, and even such mental symptoms as anxiety and irritability. Thiamine is usually measured in milligrams. See Table I for *Recommended Allowances.*

Riboflavin (also known as vitamin B_2) is a water-soluble substance belonging to the group of organic compounds called flavins. Its empirical formula is $C_{17}H_{20}N_4O_6$. Like thiamine, riboflavin is widely distributed in both plant and animal products, but most important food sources are milk, liver, other lean meats, green leaves, and whole grains. It is relatively resistant to heat, but highly inactivated by exposure to light.

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Riboflavin enters into the formation of an enzyme which assists oxidations of energy foodstuffs in the body tissues. It differs from the other major vitamins in not being associated with a long-recog-

nized disease. A deficiency produces characteristic changes in the cornea of the eye and in the skin at the angles of the mouth and nose, as well as diminished vitality, increased susceptibility to infections, and premature signs of old age. The name *ariboflavinosis* has been coined to designate a deficiency of this vitamin. Riboflavin is now measured in milligrams. See Table I for *Recommended Allowances.*

Niacin (chemically known as nicotinic acid) is a water-soluble, nitrogen-containing substance ($C_6H_5NO_2$) found in relatively large quantity in liver, lean meat, fish, eggs, tomatoes, green peas, and green leaves. We also get a substantial part of our niacin from bacterial synthesis in the intestines. Niacin is not affected by most processes applied to foods. Niacin, thiamine, and riboflavin are generally present in the same foods though the relative potency of each varies; together with some less important vitamins, which we shall not discuss, they are sometimes called the *vitamin B complex.*

Niacin resembles thiamine and riboflavin in action, functioning in tissue oxidations. Extreme deficiencies of niacin, possibly complicated by deficiencies of other members of the B complex, result in the disease *pellagra.* Since colonial days, pellagra has been associated with reliance to a large extent on corn meal as a food. We now know this is because the corn kernel contains much less niacin than wheat, and because corn is deficient in tryptophane, an amino acid required for intestinal synthesis of niacin. Pellagra is characterized by digestive disturbances (diarrhea), a peculiar rash or skin eruption (dermatitis), and nervous disorders leading in extreme cases to insanity (dementia). It is thought that some vague digestive disorders may be caused by mild deficiencies. Niacin is measured in milligrams. See Table I for *Recommended Allowances.*

Ascorbic acid (vitamin C) is like the vitamin B complex in being water-soluble. Its empirical formula is $C_6H_8O_6$. Except for liver, only plant tissues are significant sources, and it is absent in dry seeds. It is the most subject to inactivation during processing of all the vitamins.

Ascorbic acid is required to promote the building of connective tissues and cementing substances in the teeth, bones, muscles, and blood vessels, probably because it functions in the utilization of one or more amino acids. The disease *scurvy* results from a severe deficiency and is characterized by swollen, painful gums and joints, loosened teeth, fragile bones, and easily ruptured capillaries. Milder

deficiencies involve swollen, inflamed gums, tender joints, weakness, fatigue, and lowered resistance to infections. Ascorbic acid is also believed to help the body resist bacterial toxins and some other poisons such as lead. It is measured in milligrams. See Table I for *Recommended Allowances.*

Vitamin D, or more properly, the vitamins D, because at least ten different compounds exhibit its physiological properties, are complicated sterols which have similar physiological action. One of these sterols ($C_{27}H_{43}OH$) is formed when the skin is exposed to the ultraviolet rays of the sun. This was probably nature's provision for our supply, since none of the true vitamins D is present in most foods, and no ordinary food is naturally a potent source. The most potent natural sources are the fish liver oils, but egg yolk, milk, and the flesh of certain fish contain small amounts. Many foods, including milk and cereals, contain sterols which can be converted to vitamin D by exposure to artificial ultraviolet light. Vitamin D is fat-soluble and resistant to ordinary food processing.

Vitamin D (we shall use the term to cover all forms) helps ensure calcification of bones and teeth, probably by promoting absorption of calcium and phosphorus from the intestines. Severe deficiencies in infants cause the disease *rickets,* in which there is failure to deposit calcium and phosphorus in the bones, enlargement of joints, and skeletal deformities. More rarely, adults develop fragile bones as a result of an inadequate supply of this vitamin. In areas where the sun does not provide ultraviolet rays throughout the year, probably all growing children need a supplementary source of vitamin D. The same is true of pregnant and lactating women on account of their high needs, and of other adults who are not exposed to the sun. Vitamin D is measured in USP units.* See Table I for *Recommended Allowances.*

HOW FOODS MEET THE NEEDS OF THE BODY

A food which was nutritionally perfect would be one which furnished all essential nutrients in such proportion that they met all body needs equally well. No single food does this. Consequently, to be well-nourished, we must eat a variety so chosen that

* USP is an abbreviation for United States Pharmacopeia. One USP unit equals one International Unit, which is based on a definite amount of one of the pure forms of vitamin D, irradiated ergosterol.

the deficiencies of certain essentials supplied by some foods are compensated for by the abundance of the same furnished by others.)

As indicated in Table I, *Recommended Allowances* of each nutrient have been set up for different classes of individuals. Summary tables of the contributions of essential nutrients furnished by given amounts—100-gram portions, pound as purchased, and common household units, of individual foods—have also been prepared.[1]

However, because our capacity for all food is limited, before we can rate any one food as a source of a particular nutrient, it is necessary to estimate the proportion of the day's allowance furnished by a serving. Thus 1 cup of milk provides 8.5 grams of protein. Since a physically active man should have about 70 grams per day, it is evident that the cup of milk is taking care of about $\frac{1}{8}$ of his protein needs, or about 12 per cent. At the same time this amount of milk provides about 5.5 per cent of his energy allowance, 29 per cent of his calcium, 1.5 per cent of his iron, 8 per cent of his vitamin A, 6 per cent of his thiamine, 23 per cent of his riboflavin, 2 per cent of his niacin, and 4.5 per cent of his ascorbic acid. Besides showing the value of milk in contributing each nutrient, conversion of the contributions to percentages of *Recommended Allowances* makes it possible to judge relative contributions at a glance. Thus one can quickly see that milk is outstanding for its calcium and riboflavin, but meets all needs to at least the same extent as that for energy except those for iron, niacin, and ascorbic acid. It happens that in the case of niacin, this deficiency is only apparent, because milk is such a good source of tryptophane that it stimulates extra bacterial synthesis. It is appropriate to judge all contributions in relation to energy value, because this is the basic measure of the quantity of food we need to eat.

In other words, by the time we have eaten enough to meet energy needs, other needs should also be met, or we must eat an excessive total amount to meet them. Also, most people's appetites seem to be more closely related to the energy value of what they eat than to any other contributions of food. Because these percentage designations are so useful, we shall employ them most often in this book to evaluate different foods.

[1] Watt and Merrill, "Composition of foods—raw, processed, prepared," *U.S.D.A. Handbook* 8 (1950).

[2] Babcock, "Simplification of the 'long method' for calculating the nutritional value of diets," *N. J. Agr. Expt. Sta., Bull.* 7[illegible] (1950).

NUTRITIONAL STATUS IN THE UNITED STATES

There is no country where the health of many of the population might not be improved by changes in the food eaten. For most of the world population, the major food problem is getting *enough* to eat. Estimates of the number of people who suffer from this form of malnutrition vary, but it seems probable that, outside of North America, a small part of South America, Western Europe, and Russia when not suffering from the effects of war, by far the vast majority need more food. Failure to get enough food stunts bodies and ambition. It shortens life and fosters chronic disease. It makes for lowered capacity for work, often considered inborn shiftlessness by relatively well-fed Americans.

How well fed are we in the United States? What are our most serious nutrition problems? Much scientific investigation has been devoted to answering these questions in recent years. We know that our food problem is not so much getting *enough* to eat as choosing the *right kinds* to eat. We do not suffer so much from the *hollow hunger* of undernutrition described above, as from the *hidden hungers* of unbalanced nutrition which are more difficult to recognize, but which likewise take their toll in ineffective living if not in actual illness and premature death.

Mortality statistics are of little value in estimating nutritional status in this country. Malnutrition does not occur as fully developed nutritional deficiency diseases which are recognized as such and which are a primary cause of death. It appears instead in the form of widespread lesser deficiencies which cause a variety of signs and symptoms, many of which are not specific and could have a variety of causes. Probably still more prevalent are degrees of lowered vitality and resistance even more difficult to relate to a specific cause.

Surveys in which physical examinations are made by physicians who have been especially trained to recognize symptoms of mild nutritional deficiencies show that malnutrition afflicts some members of all age groups and all social and economic classes in this country. One example of such a survey is the study of the nutritional condition of junior high school children in Maine in 1948.[3] The nature of the signs of deficiency and the suggested dietary faults are given in Table II.

[3] Clayton and Ullman, *Maine Agr. Expt. Sta., Bull.* 475 (1949).

Table II. Nutritional deficiencies among Bangor Junior High School children

[Adapted from Clayton and Ullman, "Remodeling the school lunch for the teen ager," *Me. Agr. Expt. Sta. Bull.* 475 (1949)]

Nutritional deficiencies	Girls, %	Boys, %	Suggested dietary deficiencies
Found in physical examinations			
Overweight	14.7	7.1	Too many calories
Underweight	11.5	23.9	Too few calories
Signs of previous rickets (bone deformities)	32.8	35.9	Vitamin D during infancy and possibly during prenatal life
Rough, dry skin; permanent "gooseflesh" appearance	37.1	17.3	Vitamins A and C. Probably some aggravation by exposure to cold
Inflammation of eyelids, especially on margins	12.4	10.6	Vitamin A, riboflavin
Thickening of membrane covering the eye and under-surface of lid	12.4	13.2	Vitamin A
Red, thin, shiny appearance of lining of the lips	6.2	15.4	Riboflavin, perhaps other B vitamins
Cracks and scars at corners of lips	8.0	8.4	Riboflavin, perhaps other B vitamins
Changes in papillae of tongue	25.2	29.2	Niacin, other B vitamins
Inflammation of gums	16.4	25.4	Vitamin C
Decayed teeth (cavities or fillings)	89.5	86.1	Too many sweets. Possibly also shortage of vitamins A and D and of calcium
Indicated by blood tests			
Fair or poor in vitamin A	43.7	39.3	
Fair or poor in vitamin C	52.9	70.0	
Fair or poor in hemoglobin	39.4	35.2	Food shortage, probably iron

These data are especially significant, because a study of food habits was included. According to the diet records that these children turned in, 61.6 per cent of the girls and 63.1 per cent of the boys ate only a fair or poor amount of the vegetables and fruits high in vitamin A value. Sixty per cent of the girls and 66.6 per cent of the boys ate only a fair or poor amount of the fruits and vegetables high in vitamin C. Less than half of the girls and only a little over half of the boys got the three cups of milk per day which is recommended to ensure an adequate calcium supply for children of this age group. The shortage of B vitamins indicated by the signs and symptoms was related to failure to eat recommended amounts of protein foods such as meat, fish, eggs, and legumes, and also to the fact that considerable amounts of the grain products consumed were in such forms as doughnuts which are not required in that state to be made from enriched flour.*

* White flour to which thiamine, riboflavin, niacin, and iron have been added in proportions standardized by law.

The northeastern section of the United States has such geographical handicaps to good nutrition as a short growing season limiting kinds and amounts of home-grown fresh fruits and vegetables, and a long period of low ultraviolet activity in the sunlight. However, all other areas which have been studied with equal care show that signs of nutritional deficiencies vary in kind and intensity, but that they exist everywhere.

Other evidence on nutritional conditions in the United States comes from studies of family food consumption by the Bureau of Human Nutrition and Home Economics.* Data from the 1948 survey are given in Table III.

They show that there is considerable failure to meet *Recommended Allowances* for all nutrients at every level of income, but that low-income families fail more often than high. The data indicate that the nutrient most likely to be under-consumed is calcium, only 58 per cent in all income classes meeting the *Recommended Allowance.* Thiamine, food energy, ascorbic acid, and niacin are underconsumed by about 20 per cent of the families. Mere failure to meet the *Recommended Allowances* does not prove nutritional deficiency, because the allowances contain a safety margin, but it does indicate that there is danger that many who are eating below the standard are failing to maintain optimum health.

Why do so many of our population fail to attain a higher standard of nutritional adequacy? As Dr. Hazel Stiebeling, Chief of the BHNHE, has said, "In this country we are fortunate. We have no real problem of food shortages. We have good and ample farm land, our climate is favorable, we have farmers who can take advantage of the machinery, fertilizer, and technical 'know-how' that a highly industrialized, progressive country can produce."[4] Probably at least three reasons are involved in our failure to achieve the full benefits which application of what is now known about eating and health could bring. Briefly, they are ignorance, lack of resources to obtain essential foods, and unwillingness to change eating habits.

Although almost everyone is interested in good health, knowledge of how to achieve it and conserve it is not generally taught. Much of what is taught is out-of-date or confusingly mixed with unscientific folklore. The science of nutrition is relatively new, and even physicians have often failed to bring this branch of their learn-

* Hereafter referred to as the BHNHE.

[4] Stiebeling, *J. Am. Dietet. Assoc.*, 27: 369 (1951).

Table III. Adequacy of diets of urban families: Percentage of families having diets meeting the National Research Council's *Recommended Allowances* for calories and 8 nutrients, housekeeping families of 2 or more persons in the United States, by annual income class, spring (April-June) 1948 *

[*Bureau of Human Nutrition and Home Economics, Special Report* 2 (1950)]

Income class (1947 income after Federal income tax, dollars) (1)	Households, number (2)	Food energy, 3000 calories or more, % (3)	Protein, 70 gm. or more, % (4)	Calcium, 1.00 gm. or more, % (5)	Iron, 12.0 mg. or more, % (6)	Vitamin A value 5000 IU or more, % (7)	Thiamine,† 1.5 mg. or more, % (8)	Riboflavin,† 1.8 mg. or more, % (9)	Niacin,† 15 mg. or more, % (10)	Ascorbic acid,† 75 mg. or more, % (11)
All classes	1558	79	89	58	87	86	78	84	80	79
Under 1000	53	70	66	40	76	72	72	65	68	56
1000–1999	204	77	83	50	86	78	72	79	78	69
2000–2999	410	75	87	56	87	86	78	83	78	76
3000–3999	351	83	93	62	90	87	82	88	81	82
4000–4999	167	83	95	59	88	94	79	88	86	83
5000–7499	154	79	93	64	88	90	81	89	88	88
7500 and over	72	76	92	61	88	99	76	87	85	92
Not classified	147	85	88	58	84	85	76	82	81	84

* The nutritive value per nutrition unit (physically active man) per day of the food consumed at home by each household was computed and then compared with the National Research Council's recommended dietary allowances for a physically active man (revised 1948).

† Estimated average cooking losses were deducted from the aggregate value of foods consumed.

ing up-to-date, or, when recently educated, may have attended a medical school which has not yet found space in a crowded curriculum to give the subject adequate attention.

Fortunately, the basic essentials of selecting foods for health are few and simple. It is possible to hope that they can become part of everyone's education, not only of those still at school but also of older members of the population through the agency of public health nutritionists, home demonstration agents, and other home economists as well as physicians and dentists.

Lack of resources to obtain essential foods is likely to remain the real obstacle to good nutrition for all too many, until we are as ready to assume public responsibility for this item as we now are to assume certain medical expenses or burial costs. That progress is being made in supplementing inadequate incomes is indicated by our school lunch programs and by the increasing use of a standard of nutritional adequacy in providing public funds for needy families. Many who now fail to achieve adequate nutrition on their own resources might do so if they used those resources more efficiently. This, too, is an educational problem.

Perhaps the most difficult problem is persuading people who know better to change. In all branches of teaching we have been more effective in organizing and transmitting facts than in changing behavior to conform with them—the field of nutrition is no exception. If we are to make our science contribute what it should to human welfare, we must broaden it to cover this phase, and some progress is being made to this end. Technics which involve the active participation of the persons being taught, such as discussion, group decisions, etc., are being developed. These are found to be more effective in producing change than lecturing or some other forms of telling on which we have long relied.

Much hope for future improvement of nutrition comes from examination of progress in the recent past. As Dr. Stiebeling, quoted previously, continues, "Advances in food and agriculture in this country have been stupendous. Very important, nutritionally, are the substantial increases in per capita consumption of milk and of succulent vegetables and fruits over the last generation; the enrichment of white flour, corn meal, and other grain products over the last decade; and the narrowing of the dietary gap between low- and high-income families as shown by nation-wide surveys of diets of city families in 1942 and 1948."

PLANNING FOR GOOD NUTRITION IN THE DAY'S MEALS

We have pointed out that no single food meets all body needs equally well. To produce and maintain a good state of nutrition, different foods must be combined so that deficiencies of each are compensated by the surpluses of others. It is not necessary to balance every meal in this way, but in general the goal should be to have the day's meals, or at most the week's meals, meet all needs.

In the United States, people who have had no nutrition education are inclined to think that the foundation foods are bread, meat, and potatoes. Bread, meat, and potatoes are very desirable foods, but they do not balance each other's nutritive deficiencies. This would be suspected from detailed chemical analysis and can readily be demonstrated by feeding tests with animals. When white rats of weaning age (about three weeks) are limited to these three foods, they soon cease to grow normally (see Fig. 1). Other similar rats

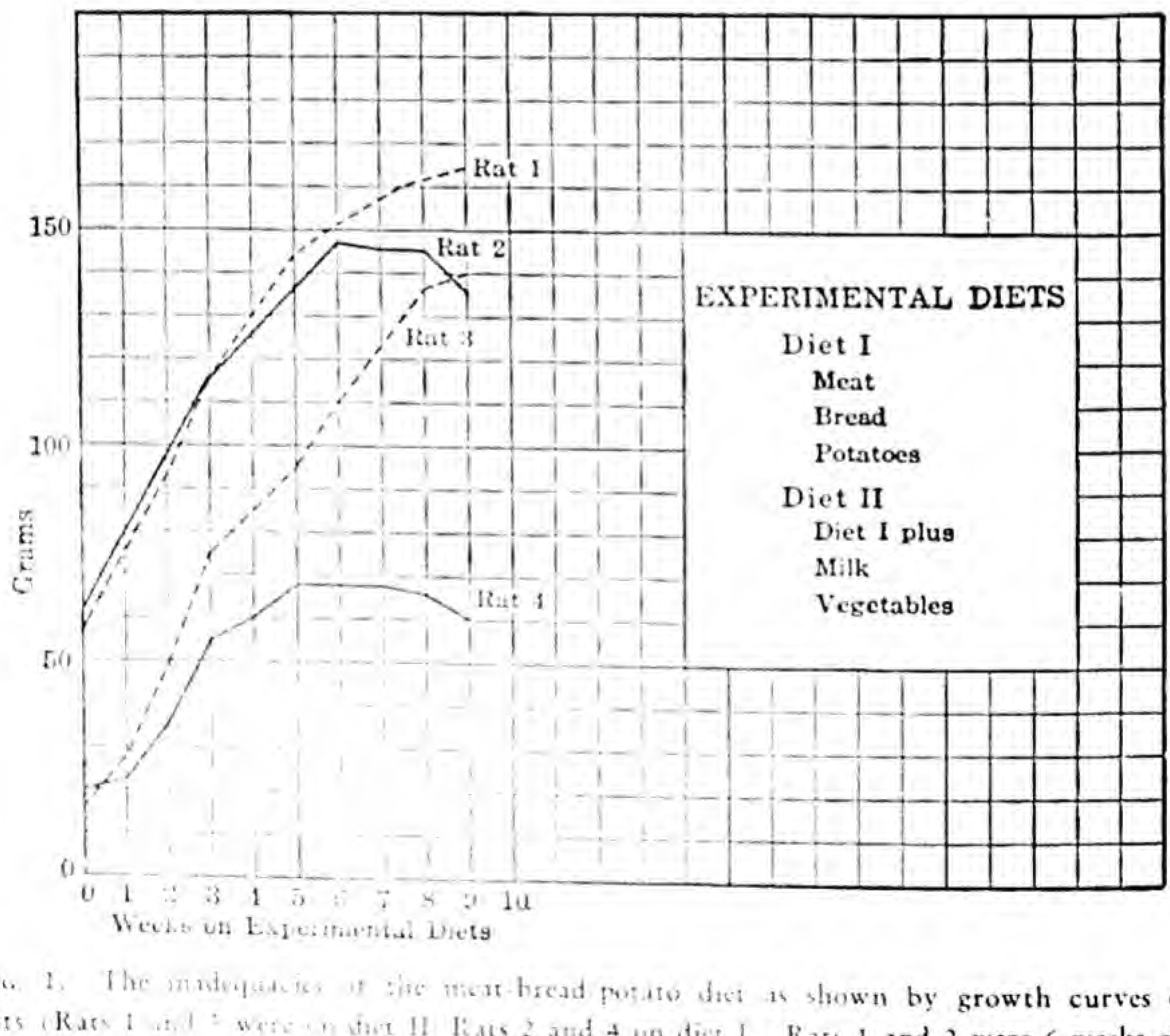

FIG. 1. The inadequacies of the meat-bread-potato diet as shown by growth curves of rats (Rats 1 and 3 were on diet II; Rats 2 and 4 on diet I. Rats 1 and 2 were 6 weeks old at the beginning of the experiment, Rats 3 and 4, 3 weeks). From data collected by a student at the University of Maine.

which receive, in addition, milk and green or yellow vegetables grow normally.*

Along with recognition of the hazards of choosing the day's meals from a limited number of foods, it is well to remember that eating a wide variety will not of itself ensure nutritional adequacy. To be certain of being well-nourished one must know how to make the right food combinations.

The most accurate method of checking the nutritional adequacy of a person's food, the method of *dietary computation,* involves the keeping of exact records of the kinds and amounts of food eaten for a period of several days or a week, computing their contributions from tables of composition, and comparing the totals with the *Recommended Allowances* given in Table I. This procedure is neither practical nor necessary for everyday use.

Simpler methods, which any homemaker can apply to test the adequacy of her menus, are the *Proportional Expenditure* method, the *Minimum Check-List* method, and the *Master Food Plan* method.

Checking the Adequacy of the Day's Meals by the Proportional Expenditure Method

In the *Proportional Expenditure* method of checking nutritional adequacy of meals, foods are classified in five groups: milk and cheese; fruits and vegetables; lean meat, fish, and eggs; bread, flour, and cereals; and fats, sugars, and accessories. When economy is desired, a fifth of the food budget is assigned to each group.[5] Dr. Sherman suggests that, at all levels of expenditure, at least as much should be spent for milk (including cream and cheese) as for meats, poultry and fish, and that at least as much be spent for fruits and vegetables as for meats, poultry, and fish. Although this method requires the keeping of only simple cost records, its accuracy is limited by the wide range in food values in such a group as fruits and vegetables, and at different times and places by the irregularities of price changes. The *Check-List* and the *Master Food Plan* methods are generally more reliable.

* Repetition of this experiment makes an excellent popular nutrition demonstration, because the deficient diet is not so restricted that it fails to resemble actual human food choices. The principal nutritional deficiencies for the rats are probably calcium and vitamin A. Rats do not require vitamin C in their food.

[5] Sherman, *Chemistry of Food and Nutrition,* Eighth Edition, Macmillan Company, New York, 1952, p. 585.

Checking the Adequacy of the Day's Meals by the Minimum Check List

The simplest of all the suggested methods of testing the nutritional adequacy of the day's meals is the *Minimum Check List.* One such check list which is widely used is "The Basic 7," which was developed by and is widely used in popular nutrition programs by the BHNHE.

The Basic 7 are:

1. Leafy, green, and yellow vegetables essential for vitamin A value.
2. Citrus fruit, tomatoes, raw cabbage, and other high vitamin C foods.
3. Potatoes and other vegetables not listed in groups 1 and 2, and fruits, valuable for miscellaneous vitamins and minerals.
4. Milk and cheese, essential for calcium and riboflavin, but valuable for other vitamins, minerals, and protein.
5. Meat, poultry, fish, eggs, dried beans and peas, nuts, valuable for protein, iron, B complex, and calories.
6. Whole grain or enriched bread, flour and cereals, valuable for energy, protein, B complex, iron, and other minerals.
7. Butter and fortified margarine, valuable for vitamin A and calories.

Other foods such as shortenings, sweets, and refined grain products are principally sources of energy and are not to be substituted for the Basic 7. See Table IV.

Table IV. National Food Guide (U. S. Dept. Agr., AIS-53, 1946)

Guide to Good Eating

All kinds of food are good . . . but for health we need variety. Our bodies are made of many materials which must be supplied in the food we eat. We must have foods that yield energy . . . foods that supply the materials for growth and upkeep . . . and foods to keep our bodies in good running order.

You can get all the right kinds of food needed for health by using this simple guide—the Basic 7. Be sure to include in your meals each day at least the minimum number of servings from each group shown on the chart. And make it a point to provide extra large servings to teen-agers and very active adults.

Foods within each group are much alike in food value, so one can replace another and give many choices in each group. A few foods are in more than one group. Though all of the food groups could, and often do, appear in one meal, this is not necessary. It's the total for the day that counts. Be sure one serving of food is not counted twice, even though it is listed in more than one group.

Keep in mind the Basic 7 when you plan your garden and what other foods to produce, store and can.

Follow the Basic 7 when you eat out.

Make lunches and lunch boxes contribute a share of the day's Basic 7.

1

Leafy, Green, and Yellow Vegetables

Raw, cooked, frozen, canned

One or more servings daily

Asparagus, green
Beans, snap, green
Beans, lima
Broccoli
Brussels sprouts
Cabbage, green
Chard
Collards
Endive, green

Escarole
Kale
Lettuce, leaf
Mustard greens
Okra
Peas, green
Peppers, green and red
Spinach
Turnip greens

Wild greens
Other greens, including salad greens

Carrots
Pumpkins
Squash, winter yellow
Sweet potatoes

2

Citrus Fruit, Tomatoes, Raw Cabbage, other high vitamin C foods

One or more servings daily

Grapefruit
Grapefruit juice
Kumquats
Lemons
Limes
Oranges
Orange juice
Tangerines

Tomatoes

Tomato juice

Cantaloups (muskmelons)
Pineapples, raw
Strawberries, raw
Cabbage, raw
Greens, salad
Peppers, green, raw
Turnips, raw

A large serving of the above vegetables can be substituted for the fruits listed in this group

If foods in Group 2 are hard to get, use more, especially raw, from Groups 1 and 3.

3

Potatoes and Other Vegetables and Fruits

Raw, cooked, frozen, canned, dried

Two or more servings daily

Potatoes
Sweetpotatoes

Artichokes
Beets
Cabbage, white
Cauliflower
Celery
Corn, sweet
Cucumbers
Eggplant
Leeks
Lettuce, head
Mushrooms
Onions
Parsnips
Radishes
Rutabagas
Salsify, or oysterplant
Sauerkraut
Squash, summer
Turnips

Apples
Apricots
Avocados
Bananas
Berries
Cherries
Cranberries
Currants
Dates
Figs
Grapes
Peaches
Pears
Persimmons
Pineapple, canned
Pineapple juice, canned
Plums
Prunes
Raisins
Rhubarb
Watermelons

Also, vegetables and fruits not listed elsewhere

4

Milk, Cheese, Ice Cream

Milk . . . . whole, skim, evaporated, condensed, dried, buttermilk

Children through teen age: 3 to 4 cups daily
Adults: 2 or more cups daily
Pregnant women: At least 1 quart daily
Nursing mothers: About 1½ quarts daily

On the basis of calcium content, the following may be used as alternates for 1 cup of milk: Cheddar-type cheese, 1 oz.; cream-type cheese, 4 oz.; cottage cheese, 12 oz.; ice cream, 2 to 3 large dips.

Meat, Poultry, Fish, Eggs, Dried Beans and Peas, Nuts

Meat, poultry, fish

Fresh, canned, or cured

One serving daily, if possible

Beef
Veal
Lamb
Mutton
Pork (except bacon and fat back)
Lunch meats, such as bologna
Variety meats, such as liver, heart, kidney, brains, tongue, sweetbreads
Game
Poultry, such as chicken, duck, goose, turkey
Fish and shellfish

Eggs . . . Four or more a week

Dried beans and peas; nuts and peanut butter

Two or more servings a week

Dried beans
Dried peas
Lentils
Soybeans
Soya flour and grits
Peanuts
Peanut butter
Nuts of all kinds

Bread, Flour, and Cereals

Whole-grain or enriched or restored

Every day

Breads:
- Whole-wheat
- Dark rye
- Enriched
- Rolls or biscuits made with whole-wheat or enriched flour
- Oatmeal bread

Crackers, enriched, whole-grain, soya
Flour, enriched, whole-wheat, other whole-grain
Corn meal, whole-grain or enriched
Grits enriched
Cereals:
- Whole-wheat
- Rolled oats
- Brown rice
- Converted rice
- Other cereals, if whole-grain or restored

7

Butter and Fortified Margarine

Some daily

Energy Foods

Basic 7 foods give energy and protect health. The foods listed below give chiefly energy. They may be eaten in addition to the Basic 7 foods, but not in place of them.

Bacon
Drippings
Lard, other shortenings
Mutton fat
Poultry fat
Salad dressings
Salad oils
Salt pork, fat back
Suet

Honey
Jams
Jellies

Molasses
Preserves
Sirup
Sorghum

Corn meal, degerminated
Cornstarch
Hominy grits
Macaroni
Noodles
Rice, white
Spaghetti

Unenriched:
  Crackers
  White bread, rolls
  White flour

Cakes
Candy
Chocolate
Cocoa
Cookies
Pastries
Sugar
Other sweets

With a little practice in the use of the Basic 7 Guide, almost anyone can soon learn to determine quickly the general adequacy of what he eats or plans for others. To ensure a high level of nutrition by this method, however, one should note (1) which foods qualify for each group—not all green or yellow vegetables have enough color to be included in group 1, for example, and (2) the number of servings specified, particularly in group 4.

Checking the Adequacy of the Day's Meals by the Master Food Plan

In the *Master Food Plan* method of checking dietary adequacy, foods are classified in eleven groups based on nutritional and general culinary roles. Although many different combinations could be devised to provide nutritional adequacy, the BHNHE has started with actual food-buying practices of families at different income

levels.* On this basis it has devised a *Low-cost Food Plan* for low-income families and a *Moderate-cost Food Plan* that allows for more variety and less home preparation for families whose incomes do not require maximum economy in food expenditures. See Tables V and VI.

The Bureau points out that both plans specify quantities of foods that meet the standards set by the National Research Council's *Recommended Allowances* in Table I for persons with different requirements. To help classify members of the family, the following additional information is given:

The dietary allowances for children are based on average needs for the middle year in each age group. They are for children of normal activity and average weight and height. If, however, children vary considerably from average weight and height for their age, the quantities in the next higher or lower age group may be more suitable. Usually changes in quantities of nutrients needed are gradual, without sudden increases or decreases such as the *Recommended Allowances* seem to imply. However, a boy or girl may have a spurt of growing when needs increase rapidly. Fortunately, appetite is usually a good guide to needed energy and may be catered to after the minimal quantities of protective foods have been eaten to ensure all-round dietary adequacy.

For adults, the recommended dietary allowances are based on the needs of a 154-pound man and a 123-pound woman, both of average height. Men and women considerably above or below the average in stature may have a higher or lower calorie requirement. Since many adults think of themselves as more active than they really are, the following illustrations of activity are given:

Sedentary persons do office work, clerking in a store, or housekeeping for a small family—the kind of work that calls for comparatively little muscular effort.

Active men do work like carpentering, ordinary farm labor, or factory work. *Moderately active* women do work such as waiting on tables or housekeeping for a moderate-sized family.

Men at *heavy work* spend 8 hours or more a day at such work as lumbering, ditch digging, or heavy farm labor.

Very active women do work such as heavy housework at least 8 hours a day.

* A subsistence diet furnishing nutrients to meet the *Recommended Allowances* for an adult has been devised which contains only wheat flour, evaporated milk, cabbage, spinach, and dried beans at a cost of less than half of that of the Bureau's low-cost plan. But, as Bureau critics point out, such an approach is entirely impractical because no one could be persuaded to eat in this limited fashion. Phipard and Reid, *J. Farm. Econ.*, 30: 161 (1948).

Table V. Master food plan at low cost. Weekly quantities of food (as purchased) for 19 age, sex, and activity groups. ["Helping Families Plan Food Budgets," *U. S. Dept. Agr., Misc. Pub.* 662 (1950)]

Family members	Leafy, green, and yellow vegetables, lb. oz.	Citrus fruit, tomatoes, lb. oz.	Potatoes, sweet potatoes, lb. oz.	Other vegetables and fruit, lb. oz.	Milk,* qt.	Meat, poultry, fish, lb. oz.	Eggs, no.	Dry beans and peas, nuts, lb. oz.	Flour, cereals,† lb. oz.	Fats and oils,‡ lb. oz.	Sugar, sirups, preserves, lb. oz.
Children through 12 years											
9–12 months	1 8	1 12	0 8	1 0	6	0 4	5	0 1	0 10	0 1	0 1
1–3 years	1 12	1 12	1 0	1 0	5½	0 8 §	5	0 1	1 4	0 2	0 2
4–6 years	1 12	1 12	1 8	1 4	5½	1 0	5	0 2	1 12	0 6	0 6
7–9 years	2 0	2 0	2 8	1 8	5½	1 8	5	0 4	2 4	0 8	0 10
10–12 years	2 4	2 4	3 0	1 12	6	1 12	5	0 4	3 4	0 12	0 12
Girls											
13–15 years	2 4	2 4	3 4	1 12	6½	2 0 §	5	0 4	3 8	0 12	0 12
16–20 years	2 4	2 4	3 0	1 12	5	2 0 §	5	0 4	3 4	0 12	0 10
Boys											
13–15 years	2 8	2 8	4 0	2 4	6½	2 0	5	0 8	4 8	1 0	0 14
16–20 years	2 12	2 8	5 0	2 8	6½	2 0	5	0 8	5 12	1 6	1 0
Women											
Sedentary	2 4	2 0	2 4	1 12	5	2 0	5	0 4	2 0	0 10	0 10
Moderately active	2 4	2 0	3 0	1 12	5	2 0	5	0 4	3 4	0 12	0 12
Very active	2 8	2 8	4 0	2 0	5	2 0	5	0 6	4 4	1 0	1 0
Pregnant	3 0	2 8	2 8	2 0	7½	2 4 §	7	0 4	2 8	0 10	0 8
Nursing	3 8	3 12	4 0	2 4	10½	2 8 §	7	0 4	3 0	0 10	0 8
60 years or over ‖	2 8	2 4	2 8	1 12	5	2 0	4	0 2	2 4	0 8	0 8
Men											
Sedentary	2 4	2 0	3 0	1 12	5	2 0	5	0 4	3 4	0 12	0 12
Physically active	2 8	2 8	4 0	2 0	5	2 0	5	0 6	4 4	1 0	1 0
With heavy work	2 8	2 8	6 0	2 8	5	2 0	5	0 10	7 12	1 14	1 0
60 years or over ‖	2 8	2 4	3 4	1 12	5	2 0	4	0 2	3 4	0 10	0 10

* Or its equivalent in cheese, evaporated milk, or dry milk.

† Count 1½ pounds of bread as 1 pound of flour. Use as much as possible in the form of whole-grain, enriched, or restored products.

‡ For small children and pregnant and nursing women, cod-liver oil or some other source of vitamin D is also needed. For elderly persons and for persons who have no opportunity for exposure to clear sunshine, a small amount of vitamin D is also desirable.

§ To meet iron allowance, 1 large or 2 small servings of liver or other organ meats should be served each week.

‖ The nutritive content of the weekly food quantities for a man and a woman 60 years or over were based on the National Research Council's recommended daily allowances for the sedentary man and woman.

Table VI. Master food plan at moderate cost. Weekly quantities of food (as purchased) for 19 age, sex, and activity groups. ["Helping Families Plan Food Budgets," *U. S. Dept. Agr., Misc. Pub.* 662 (1950)]

Family members	Leafy, green, and yellow vegetables, lb. oz.	Citrus fruit, tomatoes, lb. oz.	Potatoes, sweet potatoes, lb. oz.	Other vegetables and fruit, lb. oz.	Milk,* qt.	Meat, poultry, fish, lb. oz.	Eggs, no.	Dry beans and peas, nuts, lb. oz.	Flour, cereals,† lb. oz.	Fats and oils,‡ lb. oz.	Sugar, sirups, preserves, lb. oz.
Children through 12 years											
9-12 months	1 8	1 12	0 8	1 0	6	0 4	5	0 1	0 10	0 1	0 1
1-3 years	2 0	2 0	0 8	1 12	6	0 12 §	6	0 1	1 4	0 2	0 2
4-6 years	2 4	2 4	1 0	2 4	6	1 4	7	0 1	1 8	0 6	0 8
7-9 years	2 8	2 8	1 12	2 8	6½	1 12	7	0 2	2 0	0 8	0 12
10-12 years	3 0	2 12	2 4	2 8	7	2 4	7	0 2	2 12	0 12	0 14
Girls											
13-15 years	3 8	2 12	2 8	3 8	7	2 12 §	7	0 2	2 12	0 14	0 14
16-20 years	3 8	2 12	2 8	3 8	6	2 12 §	7	0 2	2 8	0 12	0 14
Boys											
13-15 years	3 8	3 0	3 8	3 8	7	3 0	7	0 4	4 0	1 2	1 2
16-20 years	4 0	3 8	4 8	3 8	7	3 4	7	0 6	5 4	1 6	1 4
Women											
Sedentary	3 4	2 8	1 12	3 4	5	2 8	7	0 1	1 12	0 10	0 12
Moderately active	3 8	2 8	2 8	3 8	5	2 12	7	0 2	2 8	0 14	0 14
Very active	3 12	3 0	3 4	4 0	5	3 0	7	0 4	3 12	1 2	1 2
Pregnant	4 0	3 8	2 4	3 0	7½	3 0 §	7	0 2	2 4	0 10	0 10
Nursing	4 0	4 8	3 0	3 8	10½	3 0 §	7	0 2	2 8	0 12	0 12
60 years or over ‖	3 8	2 12	2 0	3 0	5½	2 8	6	0 1	1 12	0 8	0 10
Men											
Sedentary	3 8	2 8	2 8	3 8	5	2 12	7	0 2	2 8	0 14	0 14
Physically active	3 12	3 0	3 4	4 0	5	3 0	7	0 4	3 12	1 2	1 2
With heavy work	4 0	3 8	5 0	4 4	5	3 8	7	0 6	7 0	2 0	1 4
60 years or over ‖	3 8	2 12	2 12	3 0	5½	2 12	6	0 2	2 8	0 12	0 12

* Or its equivalent in cheese, evaporated milk, or dry milk.

† Count 1½ pounds of bread as 1 pound of flour. Use as much as possible in the form of whole-grain, enriched, or restored products.

‡ For small children and pregnant and nursing women, cod-liver oil or some other source of vitamin D is also needed. For elderly persons and for persons who have no opportunity for exposure to clear sunshine, a small amount of vitamin D is also desirable.

§ To meet iron allowance, 1 large or 2 small servings of liver or other organ meats should be served each week.

‖ The nutritive content of the weekly food quantities for a man and woman 60 years or over were based on the National Research Council's recommended daily allowances for the sedentary man and woman.

Of course, a person's activities apart from his job are also important. For example, a man who walks to and from work and spends several hours working in a garden or doing chores around the house may be in the active classification even though his job is considered sedentary. The energy needs of many persons will fall midway between two of these classifications.[6]

In establishing the recommended amounts of each food group, allowance has been made for loss of vitamins in cooking. The Low-cost Plan includes more of the economical foods—potatoes, dry beans and peas, flour and cereals—and expects use of less expensive cuts of meat and lower-priced vegetables and fruits. It requires more home preparation and skill to make meals appetizing. The quantities called for allow for waste, but, if for a particular week, this is higher than average, as when corn on the cob or other fresh vegetables are purchased rather than canned or frozen products, this should be taken into account. Foods considered equivalent to fresh milk are 17 ounces by weight of evaporated milk, and 5 ounces of cheddar-type cheese. About 1½ pounds of bread or other baked goods are equivalent to 1 pound of flour.

Menus may be planned either before or after making out the weekly market order. Probably the surest way to get the recommended foods is to plan the order first and then devise menus for the week which will use all of the foods. But, if one prefers to make the menus first, adjustments can follow to provide the food groups in the right proportions.

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[6] "Helping Families Plan Food Budgets," *U. S. Dept. Agr., Misc. Pub.* 662 (1950), pp. 1 and 2.

CHAPTER 2

DIGESTIBILITY IN THE APPRAISAL OF FOODS

The process of digestion.
Meanings of the term digestibility.
  Completeness of absorption.
  Comfort after eating.
Planning for high standards of digestibility in the day's meals.
  The composition of meals.
  The size of meals.
  The interval between meals.

Being well-nourished requires more than eating the kinds and amounts of foods which provide the nutrients we need. Some of these nutrients must be digested—made ready for absorption. Minerals, vitamins, and monosaccharides can be absorbed in the form present in foods. But proteins, fat,* disaccharides, and polysaccharides must be digested—broken down into simpler, soluble forms before they can pass through the intestinal wall. Finally all nutrients must be actually absorbed into the blood stream before they can be taken to the tissues where they are used.

THE PROCESS OF DIGESTION

Digestion is partly a physical process in which movements of the digestive tract promote disintegration of food particles, but it is more a chemical process in which a series of reactions, principally hydrolyses, render insoluble and nonabsorbable constituents suitable for absorption. These reactions are largely carried on by enzymes secreted in the digestive fluids. Enzymes are organic activators, that is, compounds which participate in chemical reactions, but are not themselves used up in the processes which they accelerate. These activities take place in the mouth, stomach, and small intestine, but absorption takes place primarily from the small intestine.

* Some fat is so finely emulsified that it is absorbed without hydrolysis.

MEANINGS OF THE TERM DIGESTIBILITY

The logical and usual scientific meaning of the term digestibility is based on the nature of the process of digestion just described. In this sense, digestibility is the relative thoroughness of the process of digestion as measured by the completeness of absorption. But in popular usage the word has quite a different meaning—the ease, comfort, or mere unconsciousness of activities of the alimentary tract and other aftereffects of eating. Each meaning has a real and practical significance which deserves consideration in our food choices.

Completeness of Absorption

Factors Influencing Completeness of Absorption

The completeness of digestion refers to the difference between the quantity of a food or foodstuff consumed and the portion excreted in the feces. The percentage digested, as estimated in this way, is known as the coefficient of digestibility. For example, the coefficient of digestibility of meat protein averages about 97. All such figures obtained by the conventional methods ignore the wastes originating within the alimentary tract itself. These include the remains of digestive fluids, sloughed-off layers from the intestinal walls, and bodies of bacteria that thrive there.

A surprisingly large proportion of each of the nutrients is available for absorption when digestion is finished. It has been shown that on the average, with a mixed diet, 92 per cent of the protein, 98 per cent of the carbohydrate, and 95 per cent of the fat is absorbed. Completeness of absorption of these constituents seems to vary little among normal individuals. There is no convincing evidence that a tendency to overweight is caused by a greater than average capacity to digest and absorb food. This is contrary to popular belief that some people get "more good" out of their food than others.[1]

The principal factor causing variation in the completeness of digestion of a food or meal is the nature and amount of vegetable fiber—roughage, as it is often called. Vegetable fiber is composed of the carbohydrates hemicellulose, cellulose, and lignin. Probably none of these carbohydrates is digested by the enzymes in the body secre-

[1] Whitacre and Blunt, *J. Home Econ.*, 19: 20 (1927).

tions, but a substantial proportion of the first two may disappear, because they are used by bacteria which live in the intestine. Lignin, a woody type of fiber found in bran, is very resistant to such action. Thus the actual bulk of residue is affected by the kind as well as the amount of fiber in the foods that we eat.

Besides resisting digestion itself, fiber may interfere with the penetration of digestive juices to the nutrients and thus reduce their absorption. This applies to the protein in bran for example.[2] Digestion and absorption may also be reduced by the presence of laxative materials, whether these are taken separately or are natural constituents of the food. The reduced absorption results because the intestinal movement is so stimulated that the contents are pushed along too rapidly for digestion and absorption to proceed normally.

The kind and amount of processing are probably of less importance in their effects on digestibility than the average person thinks. However, children and persons with weak digestions may pass some foods, such as poorly chewed raw vegetables, in an almost unchanged condition.

Attempts have also been made to discover whether there is any relationship between palatability and digestibility. Are foods more completely and comfortably digested when they are liked? Everyone has experienced "watering of the mouth" when sensations were received from appetizing food. Not only flow of the saliva but also flow of the gastric juice is stimulated in this way. The flow of digestive juices which takes place before food is actually swallowed is known as appetite secretion. It is produced by favorable sight, smell, and taste stimuli. The action of these stimuli separately was tested in an experiment in which some men were blindfolded and had their ears muffled to exclude sight and hearing of frying steak; the odor increased gastric secretion in four out of seven individuals. Taste in the absence of sight and odor produced no marked psychic secretion, but the combined influence of tasting, chewing, and smelling was very pronounced and much greater than the influence of smell alone. That mere association could stimulate secretion was proved when the sound of frying was the only stimulus from the steak permitted to reach the subjects.[3]

On the other hand, very unpalatable meals may be practically as completely digested as the most attractive. This has been tested by

[2] Adolph and Wu, *J. Nutrition*, 7: 381 (1934).

[3] Miller et al., *Am. J. Physiol.*, 52: 1 (1920).

giving several subjects uniform diets served palatably and in pleasant surroundings for 7 days and comparing coefficients of digestibility for these meals with other meals having the same menus rendered unpalatable by being stirred together in a dish smeared with charcoal and served from a dirty table strewn with soiled dishes. The difference in utilization was so small that the experimenters concluded: "If the stomach and intestines can only be cajoled into making the proper effort, the unsavory concoction can be digested about as satisfactorily as can the food mixture which makes a stronger appeal. If the things we eat have proper food value, we need not worry unduly as to their digestibility and absorbability by the normal body." [3]

Thus, over short periods at least, completeness of digestion is not affected by the appetite appeal of food. The appetite secretions caused by attractive sensations from food may, however, create optimum conditions for digestion and movement of food along the alimentary tract. With some people, this may be a factor in digestive comfort, especially over long periods of time.

Significance of Completeness of Absorption in Human Nutrition

Farmers are much interested in the percentage of animal feed which can be absorbed because of its effect on the cost of production of animal products, but in human nutrition the trend to eliminate roughage, especially by refining grain products, has gone so far that digestion is often too complete. This results in so little bulk of intestinal residues that the large intestine is not stimulated to normal activity and a common form of constipation known as the *atonic* type develops.

Constipation is not so much a matter of the frequency of evacuation as of the nature of the stools. Small, hard, dry stools are difficult to propel and develop pressures on the nerve endings which cause the discomfort characteristic of a constipated condition. The fact that the discomfort disappears promptly when the stools are evacuated has convinced investigators that it is a mechanical rather than a toxic effect and is caused by pressure on nerves in the intestinal wall. Normal individuals may vary from 12 to 48 hours in the time for eliminating residues from a particular meal.

The laxative value of foods is only in part dependent upon their fiber content. Other constituents present in the food or made from

[3] Holder et al., *Science*, 51: 299 (1920).

them in the intestine by bacteria, such as organic acids and gases, may also have this effect. Thus bran has a high laxative action which corresponds to its relatively high proportion of fiber which resists digestion.[5] The fiber of vegetables and fruits disappears to a greater extent as the result of bacterial action, but some of them, cabbage for example, retain a fairly high laxative value caused by other substances, probably organic acids. Some plant residues increase the bulk of the stools because of their water-holding capacity.

The optimum amount of foods to be eaten for their laxative action varies with the individual and with the particular kind of roughage that they contain. An ounce daily of bran, probably the most effective of all foods, produces adequate laxation in healthy men when the rest of the diet is low in fiber. Not everyone requires whole cereals in large quantities, or bran, to prevent intestinal sluggishness resulting in atonic constipation. In fact, roughage in more than limited quantities may be irritating to some intestinal tracts, and nearly everyone has at some time indulged in fresh fruits and vegetables to the extent that diarrhea resulted.

Another type of constipation, known as *spastic constipation,* is a condition in which an excessively irritable intestine alternates between periods of under- and overactivity. When this condition is present, foods high in fiber may need to be greatly restricted, and a smooth type of bulk-forming material such as agar taken instead.

Good intestinal hygiene is also fostered by other practices, including consuming adequate fluids, establishing a regular routine of elimination, and cultivating a healthy emotional state. Additional useful aids to proper elimination are suitable exercises and drinking a glass or two of water, especially warm water with about 1 level teaspoon of salt per pint, upon rising. Having the water at about body temperature causes it to leave the stomach promptly. The salt retards absorption of the water from the intestine. The retained water increases the volume of intestinal contents and stimulates the contractions leading to evacuation.[6]

If these measures do not produce the desired result, one should consult a physician rather than resort to the repeated use of cathartics. These drugs, besides other possible harmful effects, destroy

[5] Williams et al., *J. Nutrition,* 11: 433 (1936). Hummell, Shepherd, and Macy, *J. Am. Dietet. Assoc.,* 16: 199 (1940). Parsons, *J. Am. Dietet. Assoc.,* 12: 11 (1936). Hoppert and Clark, *J. Am. Dietet. Assoc.,* 21: 157 (1945).

[6] McCollum and Becker, *Food, Nutrition and Health,* Fifth Edition, McCollum and Becker, Baltimore, 1940, p. 84.

natural patterns of intestinal action and develop dependence upon their use. Also, as in diarrheas of any type, they are likely to produce malnutrition resulting from poor absorption.

Comfort after Eating

To most people, digestibility is, as mentioned previously, a matter of presence or absence of awareness of digestive processes after eating. When discomfort in the digestive tract occurs after eating, they consider what they have eaten was "indigestible." We shall not include the cases in which a diseased condition of some part of the body is responsible, but limit ourselves to food as a causative agent. Also, the type of alimentary discomfort caused by the presence of pathogenic organisms and substances will be discussed in Chapter 3.

Many people attribute their digestive discomfort to specific foods or combinations of foods. Examples of the latter are lobster and ice cream, and milk and fruits, commonly believed to be unwholesome combinations, not to be eaten at the same meal. But there is no scientific evidence that foods eaten separately with impunity become generally harmful when eaten together.[7]

Individual unpleasant reactions to specific foods are known to exist. Such reactions are usually caused by an individual sensitivity to the protein of the food and are known as allergies. Food allergies may be manifested in skin disorders such as hives or eczema, in gastrointestinal disturbances, in respiratory reactions such as some forms of asthma, in nervous reactions such as dizziness and headache, and probably in other symptoms not recognized as specific. The causative food or foods can usually be identified by certain dietary or other tests. The aftereffects may then be prevented by avoiding the food at fault, or in some cases by heating the food, or by desensitization (removal of the sensitized condition by a series of carefully regulated dosages with the offending food). Common foods towards which allergic sensitivities have been manifested include wheat, eggs, milk, chocolate, cabbage, tomatoes, oranges, walnuts, strawberries, bananas, white potato, cauliflower, oats, pork, and carrots. Individuals may also be peculiarly sensitive to constituents other than the protein in foods.[8] When eliminations from

[7] Rehfuss, *J. Am. Med. Assoc.*, 103: 1600 (1934). Also, Shay et al., *Am. J. Digest. Diseases Nutrition*, 3: 235 (1936).

[8] Alvarez and Hinshaw, *J. Am. Med. Assoc.*, 104: 2053 (1935). Hughes, *J. Am. Dietet. Assoc.*, 12: 314 (1936).

the diet must be made, consideration should be given to the effect on nutritional adequacy of the diet.

When we broaden the concept of comfort as affected by digestion to cover the entire period from one meal to the next, there are two physiological effects of food which have been found to be important. One involves the time that food stays in the stomach, and the other, the effect of the amount and kinds of food eaten on the maintenance of blood sugar.

Time Food Remains in the Stomach in Relation to Comfort between Meals

The time that food remains in the stomach has been studied by taking stomach tube samples of the gastric contents at regular intervals and by following gastric activities with X-ray when a small amount of barium or bismuth has been ingested with the food. Although the two methods do not give identical results, it seems conclusive that the time food remains in the stomach varies not only with its nature and quantity but with different individuals and with the same individual under different circumstances. Thus one group of experimenters believes that individuals can be classified in two general groups, one having a slow-emptying type of stomach and the other a fast-emptying type of stomach. For example, beef and its products averaged 2 hours and 35 minutes in the stomachs of the group classified as fast-emptying, and 3 hours and 25 minutes in the stomachs of the group classified as slow-emptying.[9] Other factors affecting time in the stomach include the composition of the food, the amount eaten, the method of processing to which it has been subjected, the physical activity at the time, and the emotional state.

Fatty foods and foods high in protein leave the stomach more slowly than carbohydrate-rich foods.[10] Large amounts of food are likely to remain longer than small amounts of the same kinds. An effect of processing is exemplified by the fact that soft-cooked eggs leave somewhat sooner than hard-cooked ones. Gentle exercise, especially after a meal, tends to hasten the emptying of the stomach, but violent and exhaustive activity inhibits gastric peristalsis and secretion and lengthens the time required for emptying. This delay,

[9] Hawk et al., *Am. J. Med. Sci.*, 171: 359 (1926).
[10] Editorial, *J. Am. Med. Assoc.*, 107: 1562 (1936).

however, may be followed by a period of such rapid activity that the final emptying time is not altered.[11] Training overcomes to some extent the tendency to delay.[12]

The emotional state also affects stomach activities.[13] In one experiment when a student ate fried chicken while he was worrying about the result of an impending examination, it remained in his stomach 2 hours longer than when fried chicken was eaten a week later under better mental conditions.[14] Any excitement may have a pronounced effect upon digestive action. Strong emotions may inhibit the secretions and movements not only of the stomach but also of the small and large intestines. An excited state should be reduced by physical activity or mental distraction before one eats.[15]

The length of the period that foods remain in the stomach is considered important in relation to comfort and a general feeling of well-being. On the one hand, a meal that leaves the stomach rapidly may result in the onset of "hunger contractions" before the next meal as well as in generalized fatigue or irritability. Hunger contractions are relatively violent peristaltic movements of the stomach that occur when it is almost empty. According to one theory, these "may be the augmented efforts of an almost empty stomach to rid itself of the last residues of the foodstuffs which had been introduced."[16] When these remnants have been expelled, activity subsides, to be repeated at irregular intervals which are perhaps stimulated by gastric secretions. At any rate, these contractions are considered uncomfortable and stimulate eating for relief.

Meals that leave the stomach very slowly, on the other hand, may result in discomfort caused by distention which results from the accumulation of digestive fluids.[17] A feeling of persisting fullness or failure of appetite to appear at the next mealtime has probably been felt by everyone after eating too much food or too much of foods of a slow-leaving type. Experiments have shown that oil of

[11] Hellebrandt and Tepper, *Am. J. Physiol.*, 107: 355 (1934).

[12] Hellebrandt et al., *Am. J. Physiol.*, 109: 50 (1934).

[13] Cannon, *J. Am. Dietet. Assoc.*, 15: 333 (1939).

[14] Miller et al., *Science*, 52: 253 (1920). Also Alvarez, *J. Am. Med. Assoc.*, 92: 1231 (1929).

[15] Cannon, *Digestion and Health*, W. W. Norton and Co., New York. Especially Chapter IV.

[16] Hellebrandt and Dimmitt, *Am. J. Physiol.*, 107: 364 (1934).

[17] Todd, *Sci. Monthly*, 43: 341 (1936).

peppermint taken as an ingredient in candy, in beverages, or by itself, stimulates the emptying of the stomach. Hence the capacity to relieve indigestion is commonly attributed to it.[18]

The average meal requires about three and a half hours to leave the stomach. By regulating kinds and amount of food, one can to some extent regulate the time of onset of hunger. Appetite, or desire for food, however, is so much a matter of the psychological appeals of food—actually present or suggested—that it usually develops before hunger contractions.

The Maintenance of Blood Sugar in Relation to Comfort between Meals

Many people who have omitted a meal from their customary routine, or eaten a very light meal in place of a normal substantial one, find that in the last hour or so before the next meal they develop such symptoms as fatigue, nervousness, irritability, and possibly weakness. Evidence indicates that these symptoms are associated with a relatively low blood sugar (glucose).

Soon after eating, especially when the food is quickly digested—and absorbed—carbohydrate, such as sugar, the blood sugar rises and the symptoms disappear. Our usual pattern of eating concentrates absorption into three peak periods. The amount of blood sugar delivered after average meals would interfere with circulation if it remained in the blood until needed for energy. The normal body removes it by conversion (1) to glycogen, much of which is stored in the liver, and (2) to fat. Later, as that left in the blood is used by the tissues for work, liver glycogen is reconverted to glucose and returned to the blood along with some stored body fat.

Another source of blood sugar is surplus amino acids from digested proteins. About half of these can be converted to blood sugar.

The body protects its supply of liver glycogen. It allows the blood sugar to drop and forces the tissues to use more fat for fuel. This is especially likely to happen when the protein in the previous meal has been low, and if work is rather energetic. It is this condition which appears to cause the unpleasant weakness, irritability, etc., that many people feel when a regular meal is postponed or the last meal has been omitted, or a very light meal or one low in protein was consumed.

[18] Sapoznik et al., *J. Am. Med. Assoc.*, 104: 1792 (1935).

In an experiment conducted by the BHNHE, substantial breakfasts containing at least 500 calories and about one-third of the *Recommended Allowance* for protein produced a well-sustained blood sugar level throughout the entire morning together with a sense of well-being. In contrast, breakfasts of black coffee, black coffee and doughnuts, or containing as many as 500 calories which were high in carbohydrates often resulted in deficient blood sugar and such symptoms as hunger, weakness, headaches, and a tired feeling.[19]

Careful tests show that many persons have a lower capacity to perform physical or mental work and exhibit other such symptoms as tremor and delayed reaction time when they have had no breakfast or only a light breakfast.[20] The reactions of men to the omission of breakfast have been found to be more pronounced than those of women and may include dizziness and nausea, as well as fatigue and hunger, after strenuous exercise.[21]

A rather obvious remedy for the symptoms of low blood sugar, which many people have found immediately effective, is to eat sugar-rich foods which are quickly absorbed. This relieves the symptoms but the effect is only temporary, and the procedure is undesirable for the following reasons:

1. The peak in blood sugar thus produced is soon followed by a depressed level at which the symptoms reappear. This is probably a result of the stimulation of insulin production by high blood sugar.
2. The rapid fluctuations in blood sugar which result stimulate repeated "lunching," doubtless a factor in much obesity.
3. Foods high in sugar are usually unbalanced in nutritive quality.

At the Maine Agricultural Experiment Station, the effects of breakfasts of similar calorie value but differing in composition of the sources of the calories have been tested for their effect on blood sugar as it was measured at different intervals after eating. Average blood sugars for 25 subjects rose most rapidly and to the highest peak after the high-carbohydrate breakfast but they were followed by the lowest values before time for the next meal. A high-protein breakfast gave the highest sustained levels of blood sugar but that

[19] Orent-Keiles and Hallman, *U. S. Dept. Agr. Circ.* 827 (1949).

[20] Tuttle et al., *J. Applied Physiol.*, 1:545 (1949). Also Daum et al., *J. Am. Dietet. Assoc.*, 26:503 (1950).

[21] Tuttle et al., *J. Am. Dietet. Assoc.*, 26:332 (1950).

high in fat was satisfying and seemed to postpone the onset of hunger as well. These observations substantiate the belief that both the level of blood sugar and the length of time food remains in the stomach may affect between-meal feelings of comfort and well-being.*

PLANNING FOR HIGH STANDARDS OF DIGESTIBILITY IN THE DAY'S MEALS

The appropriate goals of digestibility in meal planning are adequate elimination and alimentary comfort combined with a persisting high level of working efficiency and freedom from weakness and irritability from one meal to the next.

The first, adequate elimination, depends primarily on the composition of the foods eaten. The second, alimentary comfort and persisting working efficiency, depends upon the composition and the amount of food in each meal and the length of the interval between meals.

The Composition of Meals

From the standpoint of promoting adequate elimination, meals should contain enough roughage to enable each member of the group to select the amount suitable for him. A whole-grain product or fruits and vegetables, especially those in the raw form, will generally meet this need.

Some fat in each meal helps give it satiety value by slowing the emptying of the stomach. Protein also performs this function, and, as has been explained, it is also valuable in helping to maintain blood sugar. Many common breakfast and lunch menus tend to be low in protein, with the evening meal containing half or more of the day's supply. This is an inefficient division from the standpoint of utilizing protein's capacity to maintain working efficiency. Most of us do our work immediately after breakfast and lunch. More of the protein consumed at night will be transformed to fat, because blood sugar is used slowly while we sleep. Furthermore, the body uses amino acids for tissue growth and repair throughout the twenty-four hours, and when we eat a large proportion of our protein in one meal it does not serve this function as efficiently.

* Unpublished work.

Good patterns of meal planning for the day carry at least one-fourth of the day's protein in each meal—perhaps aiming at one-third per meal would be better. This can be achieved by distributing the high-protein foods, such as meat, dried beans, milk, and eggs, among the three meals. When the rest of the meal is composed largely of grain products, fruits and vegetables, and sugars and fats, one of the following items should be included to bring protein up to the recommended amount for average adults:

1. One small serving of lean meat, fish, or poultry (2½ ounces cooked).
2. One serving of dried beans (1 cup cooked).
3. One pint of milk.
4. Four tablespoons of peanut butter.
5. Two large eggs.
6. Two and one-half 1-inch cubes of American cheese or five tablespoons of cottage cheese.

Thus a good breakfast might include one egg and one half-pint of milk; a good lunch, a peanut butter sandwich and one-half pint of milk; and a good dinner, a serving of lean meat or baked beans.

The Size of Meals

Comfort and working efficiency can also be promoted by dividing the day's food more evenly among the usual three meals. It is probably a good rule to have no meal contain less than one-fourth of the day's calories as well as protein. In fact, some of the breakfast studies previously referred to demonstrated that, for many people, size of breakfast was more important than its composition. Examples of 500-calorie breakfasts suitable for sedentary women are shown.

Breakfast 1		Breakfast 2	
Citrus juice	4 ounces	Grapefruit	½
Rolled oats	¾ cup	Sausage links	3
Milk	1 cup	Milk, skim	1 cup
Egg	1	Toast	2 slices
Toast	1 slice	Butter or margarine	1 tablespoon
Butter or margarine	½ tablespoon	Coffee if desired, black	
Coffee if desired, black			

The Interval between Meals

We do not know whether a three-meal-a-day schedule is ideal or not. Many of the world's peoples customarily follow a four- or five-meal pattern. Of course, this does not mean that they eat *more* food, but simply that they divide their intake into a greater number of separate meals. The common belief has been that the stomach should have "rest" periods, and that since 3 to 4 hours are required for average meals to leave the stomach, the interval between meals should not be less than this. Yale physiologists have maintained, however, that "there are no indications that the stomach needs rest or that it does rest when empty." They point out that hunger contractions begin before it is completely empty, and that they become painfully increased when it is empty. Furthermore, they declare, "It is large meals and not frequent meals that put a burden upon the digestion." [22]

Another common belief holds that eating slows down mental work, but sluggishness after meals is a result of overeating. Attentiveness and the speed and accuracy of mental work are greater after light than after heavy meals, it is true, but this is merely added evidence in favor of dividing the daily food intake more evenly between the three meals or for increasing the number of meals.[23]

Evidence is accumulating which shows that omitting breakfast or lunch, or eating only very lightly at one or both of these mealtimes, is a very common habit among us, and that it may be a cause of fatigue and irritability if not of malnutrition. Eating more substantially at these meals and/or adding midmorning or midafternoon snacks produce favorable effects.

In a study of the behavior of nursery school children, it was concluded that most of the children were benefited by a midmorning serving of fruit juice, and none showed any detrimental effect. The benefits included relief from fatigue, reduced irritability and tension, and a visible feeling of satisfaction and well-being over the hours until lunchtime.[24]

Children of school age also show similar symptoms of fatigue, inattentiveness and difficult behavior which are a result of break-

[22] Haggard and Greenberg, *Diet and physical efficiency; the influence of frequency of meals upon physical efficiency and industrial productivity*, Yale University Press (1935).

[23] Laird et al., *J. Am. Dietet. Assoc.*, 11: 411 (1936).

[24] Keister, *J. Am. Dietet. Assoc.*, 26: 25 (1950).

fasts and lunches of inadequate size. The National School Lunch Program has had as one of its major purposes, the improvement of the state of nutrition of this portion of the population. But recent studies show that the size of the lunch provided does not make adequate allowance for the differences in requirements at different ages. Fast-growing high school children become hungry soon after eating. Besides interfering with effective study, such hunger leads to discipline problems and to unbalanced nutrition when an attempt is made to "fill up" somehow with the only type of supplementary snacks usually available—candies, cookies, and soft drinks.[25]

Failure to get three substantial meals is a habit which is often carried to college or acquired there. In one university it was found that only 4 per cent of the women students ate an adequate breakfast containing (1) fruit or fruit juice, (2) cereal with milk, or an egg, (3) milk or cocoa made with milk, and (4) whole grain or enriched breadstuffs with butter or margarine fortified with vitamin A.[26] It was calculated that those who ate no breakfast ended the day with total diets which were low in important nutritional essentials. Students who want to make the most efficient use of class and study time and have the additional energy to enjoy college activities would do well to consider the advantages of regular eating of three well-balanced meals, each of which contains the recommended minimum of at least one-fourth of the day's calories and protein.

The optimum number and size of meals as factors in the efficiency of both office and factory workers have also been investigated. It is difficult to control the experimental situation in such a way that improvement in output or state of well-being can be definitely attributed to food alone. Merely taking time out is likely to have these effects whether one eats or not. Furthermore, the special attention that groups receive in the setting up of an experiment improves morale, and this alone may account for better work. However, the distribution of food throughout the work period as well as the nutritional adequacy of the total amount consumed, it is generally agreed, has importance. The maintenance of blood sugar is probably more difficult for some individuals than others. In any event, those who are aware of some of the symptoms which have

[25] Clayton and Ullman, *Me. Agr. Expt. Sta. Bull.* 475 (1949). Also Hathaway et al., *Am. J. Public Health*, 40: 1096 (1950).

[26] Jackson and Schuck, *J. Home Econ.*, 40: 317 (1938).

been discussed might well examine their eating routines. It should be emphasized that between-meal snacks should not consist of unbalanced sweets or of extra calories which lead to obesity.[27]

Even when one is restricting calorie intake to reduce weight, it is advisable not to omit meals. Hunger can best be minimized and working efficiency maintained by distributing the food over the day, perhaps by eating more often than usual. This results because the carbohydrate and protein will be used in larger proportion as blood sugar rather than converted to body fat. Only a small proportion of fat molecules can be reconverted to blood sugar.

In summary, to obtain optimum digestibility:

1. Meals should contain enough roughage in the form of whole-grain products and fruits and vegetables to enable individuals to meet their needs for regular elimination.
2. The day's food should be divided into at least three meals, each containing at least one-fourth of the day's calories and protein. Between-meal snacks may well be included for young children and any others who find they improve their working efficiency and feeling of well-being. Such snacks should consist of fruit, milk, or sandwiches rather than unbalanced sweets. They should be taken into account in planning the whole day's eating to avoid excessive calories.

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CHAPTER 3

SANITARY QUALITY IN THE APPRAISAL OF FOODS

Legal protection against unwholesomeness in foods.
Infections acquired from contaminated food.
- Bacterial infections transmitted to man by food.
- Animal parasites transmitted to man by food.

Intoxications caused by food.
- Intoxications caused by bacterial toxins.
- Naturally poisonous plant and animal products.
- Organic and inorganic contaminants of food.

Planning for high sanitary quality in the day's meals.

By sanitary quality of food we mean its freedom from pathogenic organisms and substances. Excluding the nutritional deficiency diseases, allergies, and overindulgences, the disorders correctly attributed to food are primarily *infections* and *intoxications* or poisonings. Infections are caused by pathogenic organisms. Intoxications are produced by the products of organisms, by a natural constituent of the plant or animal which is being eaten, or by contamination with poisonous substances in the processes of production and distribution.

Food spoilage and food unwholesomeness are not identical conditions. Food is considered spoiled when obvious and unpalatable changes have occurred which make it inedible to civilized persons under ordinary conditions. Not in all cases is such altered material unwholesome or causative of illness when eaten. This is proved by customs of primitive peoples and by the experiences of the needy, the victims of war, or of persons separated temporarily from civilization. But the presence of no detectable change, or of the expected qualities of palatability, is no guarantee of wholesomeness. Pathogenic organisms and substances by no means consistently warn the eater of their presence. For example, fresh milk from a tubercular cow would appear to be as palatable as that from a healthy cow but would probably be hazardous to drink.

LEGAL PROTECTION AGAINST UNWHOLESOMENESS IN FOODS

The Council on Foods and Nutrition of the American Medical Association states that to be rated a wholesome food a product should (1) make a significant contribution to human nutritional requirements, (2) be clean and free from microorganisms, and (3) be free from chemical additives * in kinds or amounts that might be directly injurious to the body or reduce the nutritional value of the food.[1]

Deliberate addition of harmful substances and contamination with them incidental to processing or handling of food are forbidden by the federal laws which apply to all products in interstate trade. According to the federal law, a food is deemed to be adulterated and hence barred from interstate trade, "if it bears or contains any poisonous or deleterious substance which may render it injurious to health," or coal tar dyes other than those approved by the Food and Drug Administration.

Besides declaring a food to be adulterated if it contains any harmful or deleterious substance, the federal food law furnishes other protection related to the wholesomeness of food by the following provisions, also deeming a food to be adulterated: (1) "if it consists in whole or in part of any filthy, putrid, or decomposed substance, or if it is otherwise unfit for food," (2) "if it has been prepared, packed, or held under unsanitary conditions whereby it may have become contaminated with filth, or whereby it may have been rendered injurious to health," (3) "if it is, in whole or in part, the product of a diseased animal, or of an animal which has died otherwise than by slaughter," and (4) "if its container is composed, in whole or in part, of any poisonous or deleterious substance which may render the contents injurious to health."

Another provision of the federal law which helps ensure wholesomeness of foods is the authority granted to the Food and Drug

* "Additives" are defined as chemicals incorporated into foods during growing, storing, or processing. They are *incidental* when they are residues of pesticides required for production of crops or are otherwise introduced accidentally. They are *intentional* when added purposely to preserve or improve the quality of a product. Artificial coloring, synthetic flavors, sweeteners, mold inhibitors, bactericides, antioxidants, emulsifiers, and minerals and vitamins are among the intentional additives.

[1] Council on Foods and Nutrition, *J. Am. Med. Assoc.*, 146: 477 (1951).

Administration to promulgate "standards of identity." These are definitions of what may be contained in such basic foods as bread, cream, cheese, etc. Their principal purpose is to help consumers by creating a considerable degree of uniformity in composition of the more common foods, but, by defining the ingredients or composition, they exclude all other substances, including any of doubtful wholesomeness.

The federal law, which, as we have stated, applies only to foods moving between the states, is supplemented by state laws, and in some cases by city ordinances, to cover foods produced and sold within a state. People have become so accustomed to the relative security that our laws guarantee that they little realize the situation existing before the first federal law was enacted in 1906. At that time, a large proportion of commercially canned food was adulterated or improperly prepared, and peas and beans were frequently colored with salts of copper, a procedure now believed to be unwholesome. Harmful preservatives, such as boric acid, were often added. Food colors which were hazardous to health were often used.

In spite of the great improvement in wholesomeness of food brought about by federal, state, and local laws, a number of hazards remain. These include (1) lack of funds for adequate enforcement of existing laws, (2) failure of the laws to cover some dangers to the health of consumers, and (3) individual ignorance and carelessness that no law could prevent. Some of these problems will be explained in the pages that follow.

INFECTIONS ACQUIRED FROM CONTAMINATED FOOD

Along with having too little to eat, the other major food problem of the world as a whole is food that is unwholesome because it is infected with harmful microorganisms. Such unsanitary food brings a high infant death rate and increased mortality at all ages, and, in the form of such chronic infections as dysenteries, undermines the vitality of almost the entire population in many large areas. In little over half a century, the findings and applications of the science of microbiology have brought us in the United States such a high degree of safety that we often fail to appreciate the benefits we derive from them.

Bacterial Infections Transmitted to Man by Food

Most of the infections transmitted through food are bacterial—that is, they are caused by the presence of one-celled plants. Certain human diseases in this group may be spread by other types of contact so that we may consider transfer by food as incidental. These infecting organisms can remain alive in foods with which they have been brought in contact. In such cases, the human infections develop when the contaminated food is eaten without previous heating to a temperature that kills bacteria. Pasteurization, heating to 165 degrees F. (74 degrees C.) for a few seconds is sufficient. This group includes typhoid fever, scarlet fever, diphtheria, colds, pneumonia, meningitis, whooping cough, trench mouth, certain dysenteries, human tuberculosis, infectious hepatitis, *Salmonellae* or paratyphoid infections, and possibly poliomyelitis.

Common ways by which foods become infected with bacteria of this type are:

1. Handling of food or containers by persons ill with the disease or by persons who carry germs but are not themselves ill (this applies to typhoid, paratyphoid, and diphtheria).
2. Sewage contamination of water or food.
3. Contact of the food with insects which have had access to the excreta or secretions of persons ill with the disease.

Probably *Salmonellae* produce more infections carried by food than any other organism in this group. They are often classed as *food poisonings*. This term is rather loosely applied to all sudden gastrointestinal illnesses among those who have eaten the same food. "Ptomaine poisoning" is now considered a misnomer. Ptomaines are the products of the decomposition of proteins, and most of them are not toxic when taken by mouth. Acute gastrointestinal illnesses resulting from unwholesome food are known to be caused principally by some one of four groups of bacteria with which the food has been infected and held under conditions suitable for multiplication. Two of the four form toxins in the food which are the real cause of the illness. These will be discussed later. The other two, several species belonging to the *Salmonellae* group and *Streptococci*, cause true infections.

The *Salmonellae* have an incubation period which usually varies from about 12 to 24 hours but may be as long as 8 days. Gastro-

intestinal symptoms are followed by a fever, and, although the disease is usually mild, there have been fatalities and recovery takes longer than in the staphylococcic food poisoning discussed later. Paratyphoid is a name sometimes applied to this disorder. Causative bacteria are most often carried by foods containing milk products, eggs, meat, and include cake fillings and cream or custard pastries. The food may be infected by human or animal carriers, for example, rats, mice, poultry, hogs, and household pets, and water or dust. Poultry, especially ducks, sometimes infect their own eggs. Insects, including flies and cockroaches, may transmit these organisms. The germs can multiply in food, and, although the numbers are reduced by refrigeration, infection is still possible. *Streptococci* which are apparently normal inhabitants of the intestines of man and some other animals and cause no harm there, can multiply in some foods. When such foods are eaten, in from 5 to 18 hours they produce gastrointestinal symptoms which are usually mild and disappear in a day or two. Ham, creamed eggs, and cream pie have been responsible for this kind of infection.[2]

A second group of bacterial infections spread by food causes animal diseases and is transmitted to man through a product, milk or meat, of the infected animal. It includes septic sore throat, bovine tuberculosis, undulant fever, and tularemia.

Septic sore throat is a peculiar form of sore throat occurring in epidemic form and almost always connected with the milk supply in its distribution. Cows receive their infection from human beings and suffer from an inflammation of the udder, one form of mastitis. The bacteria, which belong to the *Streptococci* already mentioned, are secreted in the milk and thus spread. The term "septic sore throat" is sometimes loosely applied to any type of severe sore throat in which streptococcic bacteria are the cause but were not acquired in a milk epidemic.

Bovine tuberculosis may be transmitted to man, especially to children, through raw milk or undercooked meat from infected cows. This disease is now extensively controlled by eliminating infected cows, as will be discussed later in connection with milk and meat.

Undulant fever (Brucellosis) is the name applied to the human form of bovine contagious abortion (Bang's disease). Cases are known to occur in every state, and it is believed that the majority

[2] Buchbinder et al., *Pub. Health Repts.*, 63: 109 (1948).

are passing unrecognized. The germ may be transmitted to man through milk of the infected cow.

Tularemia is a disease attacking ground squirrels, pheasants, rabbits, and some other wild animals in many states. Hogs and turkeys which have eaten infected animals may also contract this disease and transmit it to humans. People may contract it during the handling of the meat of diseased animals or by eating the imperfectly cooked meat. The disease is sometimes fatal, and convalescence is long and tedious. In states where it is known to be prevalent among wild rabbits, it is scarcely worth while to take the risk involved in eating them. Although the germs themselves are killed in cooking, the danger of contracting it by handling the raw meat is great.

Another infection which it is now recognized can be transmitted to man through milk from infected cows is *Q fever*. This disease is caused not by bacteria but by microorganisms called *Rickettsiae*.

The infections carried by milk may be prevented by proper pasteurization, but this process is not required by federal or state laws or, except in larger cities, by local ordinances. All meat moving in interstate commerce is screened by federal inspectors who examine animals before and after killing to eliminate any parts which may be dangerous to human health. But meat which is sold within the state where it was produced is not subject to such examination unless there happen to be local laws requiring it.

Animal Parasites Transmitted to Man by Food

The most important of these organisms include a protozoan (single-celled animal), three tapeworms, and a roundworm. The protozoan is an ameba which causes the disease amebic dysentery. It is transmitted by food or water contaminated by sewage or a human carrier.

Tapeworms have been recognized as intestinal parasites of man since a very early day. Infection takes place when uncooked meat which contains the immature forms is eaten. The three species infecting man are pork, fish, and beef tapeworms. The flesh of none of these animals should be eaten raw.

Roundworms. One of the roundworms, *Trichinella spiralis*, frequently infests pork. If such meat is eaten when it has not reached a temperature of 137 degrees F. (58 degrees C.), the immature worms, which are encysted in the muscle and other tissues of the hog, are

freed from their coverings by the action of the digestive fluids, whereupon they develop to maturity in the small intestine and reproduce. The new generation migrates to various parts of the body, causing a diseased condition known as trichinosis. Without doubt many cases pass unrecognized, but numerous post-mortem examinations and other tests indicate that 10 to 20 per cent of adults have been subjected to at least a mild infection at some time in their lives.

The United States has the greatest problem of trichinosis of any country in the world.[3] Hogs become infected by eating raw pork scraps in garbage or garbage infected with the droppings of rodents which have acquired their infection from garbage or by cannibalism. Inspection to permit condemnation of infected meat is difficult and has been considered too expensive to require. Infection in hogs could be eliminated if garbage were fed only after cooking as has long been recommended by the United States Public Health Service, but this would be hard to enforce with scattered small producers.

Another possible method of control is to require suitable processing of pork and pork products to kill the worms when they are present. Cooked products can of course readily be rendered safe. *Trichinellae* can also be killed by freezing, the time necessary depending upon the temperature employed. At 0 degrees F. (−18 degrees C.), which is available in most home freezers, 72 hours is sufficient. If this were practiced with all pork marketed, within a very few years trichinosis in hogs could be practically eliminated. Perhaps in time health authorities and consumers will insist that pork be as safe as milk which has been pasteurized.[4]

INTOXICATIONS CAUSED BY FOOD

As indicated earlier, food intoxications are caused by the presence in food of unwholesome substances and include three main types: (1) those caused by bacterial toxins, (2) those caused by natural constituents of a plant or animal, and (3) those caused by contamination with extraneous poisonous substances.

Intoxication Caused by Bacterial Toxins

The U. S. Public Health Service limits the use of the term *food poisoning* to intoxications caused by two kinds of bacteria—*Staphy-*

[3] Hall, *Pub. Health Repts.*, 52: 873 (1937).
[4] Gould, *J. Am. Med. Assoc.*, 129: 1251 (1945).

lococci and *Clostridium botulinum*.[5] The most common cause of food poisoning is the production in foods of a toxin by *Staphylococci*. These are pus-forming bacteria widely scattered in nature and ordinarily present on the surface of the skin, under the fingernails, and even in the nose and throat. They are responsible for boils and other infections in which pus forms when the skin is injured. If *Staphylococci* get into foods such as milk, cream, and egg sauces, custards, cake fillings, ready-to-eat meats, gelatin, cheese, or gravy, and are held under conditions which permit them to multiply, they produce the toxin which is responsible for illness when the food is eaten. Gastrointestinal symptoms usually develop within 2 to 4 hours after eating, and, although these may be extremely severe, recovery is nearly always rapid and complete.

The most frequent source of contamination of food with *Staphylococci* is a human handler. These germs together with those of the *Salmonellae* group have been found to be very common in custard-filled bakery products such as éclairs, napoleons, and nesselrode pies.[6] The germs can be destroyed at temperatures below the boiling point, but the toxin is not entirely destroyed when the food is boiled for 30 minutes. Foods which are contaminated before inadequate heating, or after heating, and then held for 3 or 4 hours under inadequate refrigeration are hazardous to eat. Holding temperatures of 60 to 115 degrees F. (16 to 46 degrees C.) are the range for rapid multiplication of *Staphylococci* and are hence to be avoided.

The idea that foods need to be cooled to room temperature before refrigeration has been shown to be false. Placing the more susceptible foods in a refrigerator within a half hour after cooking is finished is desirable because it shortens the time the temperature remains in the danger zone. Putting the foods in the serving dishes before refrigeration also speeds up cooling.[7] The conditions of quantity food preparation, especially with the facilities improvised for single large events, such as picnics, banquets, etc., are especially hazardous.

The other toxin former responsible for food poisoning, *Clostridium botulinum*, is an organism that develops in canned foods such as meats and nonacid fruits and vegetables, or more rarely in improp-

[5] Feig, *Am. J. Pub. Health*, 40: 1372 (1950).

[6] Abrahamson et al., *Food Res.*, 17: 268 (1952).

[7] Black and Lewis, *J. Am. Dietet. Assoc.*, 24: 399 (1948).

erly cured meats. It is limited to foods of this type, because it grows only in the absence of air. The organism is probably non-pathogenic in itself, but it produces a toxin during its development that is such a potent poison that even to taste the food may be fatal. Gastrointestinal symptoms may appear within 24 hours, but they may be delayed. Later the nervous system is injured. Death is usually a result of respiratory failure. Antitoxic serums, if administered soon enough, usually prevent death.

Spores of this organism in nonacid foods cannot be destroyed by short periods of boiling; consequently, the safest method of canning the susceptible foods is to process them for a sufficient time in a pressure cooker. It is also important to use only fresh, unspoiled materials for preservation. The bacteria are present in most soils. This subject will be discussed more completely in connection with the canning of vegetables.

Not all sudden epidemics of a gastrointestinal nature are caused by contaminated food. Such disturbances, often quite mild and brief, occur most frequently among groups living or working in close contact—school children and residents of dormitories or other institutions, for example. Sporadic cases may appear over a period of weeks or months to be followed by a large outbreak affecting from 15 to 100 per cent of the persons in the group. Symptoms include loss of appetite, nausea, vomiting, diarrhea, dizziness, aching, and abdominal discomfort or cramps, sometimes accompanied by fever. Although the cause is unknown, it is probably a germ transmitted by contact or through the air. The possibility of this type of disorder should be ruled out before there is large-scale destruction of suspected food or blame placed on the management of public eating establishments.[8]

Naturally Poisonous Plant and Animal Products

Poisonous plant and animal products are sometimes eaten. Their toxicity may be constant for the species, or occasional as a result of some seasonal or environmental factor.

Plant species which when eaten are poisonous to man include certain mushrooms, spotted hemlock, aconite, and meadow saffron. The roots of poison hemlock and aconite are sometimes mistaken for

[8] Reimann et al., *J. Am. Med. Assoc.*, 127: 1 (1945).

horseradish, and leaves of meadow saffron are accidentally included in green salads. The poisonous substances in all belong to the group of chemical compounds known as alkaloids. Rhubarb leaves contain such a high concentration of oxalic acid that they have occasionally caused illness when they were eaten as greens.

Among animals certain species of fish, owls, and hawks are poisonous. In the United States, however, illness caused by fish or shellfish is practically always due to allergy or contamination.

Examples of occasional toxicity in plants are potato poisoning, caused by the accumulation of solanin during sprouting or exposure to the sun, and ergotism, caused by contamination of rye flour with a fungus which occasionally develops in place of the grain. True solanin poisoning is probably very rare. Illness associated with potatoes is more likely to be caused by bacterial contamination, especially if they are served as potato salad or creamed potatoes without proper refrigeration during holding.

Occasionally, plants which are ordinarily wholesome accumulate unwholesome minerals from the soil. Selenium in some soils is known to appear in the grains and grasses grown there in sufficient concentration to injure the health of local livestock. Although the hazard to people living in the region is less because they always eat some foods imported from other areas, the possibility of lesser damage to their health exists. The possibility of the accumulation in soils of spray residues, lead for example, to a point where the amount absorbed by vegetation is excessive has also received scientific attention.

Animal products, ordinarily wholesome, are known to develop occasional toxicity. Certain species of fish become poisonous at the spawning season; and mussels and clams in some areas are poisonous in the summer and early fall only. Milk or flesh from a cow having the disease called "trembles" causes *milk sickness* in man. Eating certain species of weeds (white snakeroot and the rayless goldenrod) which contain a toxic substance cause the disease in the cow. At one time the disease was fairly common in the southeastern states.

In concluding the discussion of naturally or occasionally poisonous plants and animals, it should be noted that the proportion of the species of either which is involved in health problems of this sort is remarkably small. They represent only minor hazards.

Organic and Inorganic Contaminants of Foods

Harmful substances may either be added to foods or dissolved by foods from certain types of utensils or containers.

The Problem of Added Substances and Wholesomeness of Food

Additions of substances which are harmful may be accidental or deliberate. An example of the accidental type of contamination is an incident in which numerous cases of poisoning among patrons of a hotel were traced to imperfect removal of a cyanide silver polish from the silverware. Of this type also are the too frequent cases of death caused by the accidental but criminally careless incorporation of poisonous insect powder in food, of boric acid instead of lactic acid in babies' milk, etc. A suggestion which should be adopted to prevent mistaking insect powders for flour or salt is to require them to be colored green, red or some other color unusual in a food ingredient. Boric acid, an eye wash, has been said to be of so little value that it should be eliminated from routine use with babies to prevent its substitution for the lactic acid sometimes needed in a baby's formula. Fatalities caused by such accidents are common enough in institutions, commercial eating establishments, and homes to warn us to take adequate precautions to keep poisons where they will not be confused with foods or substances added to food.

The major problem today involving deliberate additions of various chemical substances to foods is that of determining whether they are potentially harmful or not. In fact, some chemicals added to foods actually increase nutritive value. These include such minerals as calcium which is present in some types of baking powders and is a permissive ingredient in enriched flour and bread. Iron is a required addition in enriched flour and bread. Iodine is a generally recommended addition to salt.

Purified or synthetic vitamins are also employed to enhance the nutritive value of foods. Thus vitamin A is commonly added to oleomargarine to make this food resemble butter in this nutrient. Thiamine, riboflavin, and niacin, like iron, are required additions to enriched flour and bread. They may also be employed in forti-

fying other cereal products. Fruit juices naturally low in ascorbic acid are often supplemented with the synthetic form. This vitamin is added to other fruit products to improve color and flavor retention during processing, incidentally increasing nutritional potency. Vitamin D is fairly widely added to milk and is a permissive addition to the enrichment formula for bread and flour. It is also included in some other cereal products.

In general, these examples of the addition of chemicals which improve nutritive value have widespread scientific acceptance. However, many nutritionists question the advisability of indiscriminate additions of this type for the following reasons: [9]

1. They may give consumers a false sense of security. For example, adding vitamins to sugar or candy does not make them complete foods, and advertising their presence might tend to mislead the public into thinking so.
2. They tend to discourage consumption of simple, natural foods which may contain unknowns of nutritional importance.
3. Unlimited fortifications of foods with certain nutrients, vitamin A or vitamin D in particular, might result in consumption of excessive amounts of these constituents.

In general, the wisest policy in regard to the addition to foods of nutrients in purified form is to use them (1) to restore values reduced by processing as in enriched white flour and bread or in fortifying other cereal products, (2) to standardize or equalize foods which otherwise play similar nutritional roles, for example adding vitamin A to oleomargarine to make it more comparable to butter, and (3) to employ a common food as a carrier of a nutrient which tends to be widely deficient among the group consuming it, as in adding vitamin D to milk. With these exceptions it is better to work toward improving nutrition by (1) encouraging better selection of foods, (2) providing foods which are naturally more nutritious through improved varieties, methods of processing, etc., and (3) by reinforcing the values of some prepared foods by the use of other natural foods of high value, such as dry skim milk, soya flour, and dried yeasts.[10]

The deliberate addition of nonnutritional chemicals to foods is being increasingly practiced and results in health hazards which

[9] Council on Foods and Nutrition, *J. Am. Med. Assoc.*, 129: 348 (1945).

[10] Cowgill, *J. Am. Med. Assoc.*, 142: 721 (1950).

are difficult to evaluate. So far as substances of known toxicity are concerned, the only exceptions the law allows involve authorization given to the Federal Administrator to set tolerances for harmful substances considered necessary in the production of a food, limiting the quantity to a level considered safe for public health. Under this provision, tolerances have been established for the amount of lead, arsenic, and fluoride left on apples and pears as spray residues. In some areas these fruits have to be specially washed before marketing to meet the tolerance requirements. However, the tolerance for fluoride has not been upheld in court, and those for lead and arsenic are considered merely informal guides to the trade. It is very difficult to provide evidence to defend a particular level of a potentially poisonous substance as a maximum in the interest of public health.

Insecticides harmless to humans are available for members of the cabbage family and other fruits and vegetables requiring their use, but consumers of all these foods should still exercise caution. Poisonous sprays may still be used, and enforcement of the tolerances may also be imperfect. Thorough washing of all fresh fruits and vegetables whether they are to be eaten raw or cooked is advisable. Discarding the bud and stem depressions in apples and pears removes residues often difficult to wash away.

However, to combat pests or to improve palatability or keeping qualities, the practice of adding substances which are not readily demonstrated to be harmful is very difficult to control. It has been estimated that several thousand brands of new insecticides, fungicides, and herbicides have appeared on the market in recent years. The residues of some are very difficult to remove—others become incorporated in both plant and animal tissues and cannot be removed. Very little is known about possible chronic effects of long-time eating of foods contaminated with some of these products. Other chemicals added directly to foods include bread softeners, emulsifiers, antioxidants (substances retarding development of rancidity in fats), other preservatives, flavor enhancers, bleaches, etc., which may or may not have been subjected to adequate animal tests for possible toxicity. In fact, it is doubtful whether any animal test is always indicative of effects on humans. Examples of chemicals for a time added to food or acquired through an insecticide which have later been forbidden are nitrogen trichloride used

as a bleaching and maturing agent for flour, and DDT * used as a fly-killing spray on milch cows.

Though flour treated with nitrogen trichloride has not been shown experimentally to be harmful to human subjects, it produced nervous disorders in dogs and some other animals, and its use was ordered discontinued.[11] DDT, a fly killer which came into wide use during the war, was for a time directly applied to cows, to barns, and to some feeds. When it was found that small amounts of the spray might appear in milk, experimental studies of toxicity were conducted. Results showed that, although limited intake of DDT produced no immediate effects, some of the drug was stored in body fat. During periods of undereating especially, these stores might be released in toxic quantities. Hence the spray is no longer recommended for use in the dairy industry.[12]

Cases such as these warn us to be more cautious about additions to foods of any chemical of uncertain physiological effects. For many years the Federal Food Administration has forbidden chemical preservatives except sodium benzoate and sulfides, and restricted these to certain foods only. But the newer uses of chemical additives—improvement of palatability directly as ingredients in processing or indirectly as pest killers—present difficult problems requiring constant vigilance on the part of our health officials. To help perform this public function, the National Research Council, a semiofficial board of scientific authorities, has set up a Committee on Food Protection.[13] Although our laws deem foods to be adulterated, and hence illegal for sale, when they contain harmful substances, there is no requirement that chemicals added to food be proved nontoxic *before* the product is marketed. The only way to prevent questionable additives is to establish a definition which restricts the ingredients permitted in products sold under a particular name, bread for example (see Chapter 5). But this procedure takes much time and cannot feasibly be applied to all possible types of food on the market. The most practicable remedy is the revision of existing laws to put the burden of proof of harmlessness of doubtful additives on the food manufacturer.

* Diphenyltrichloroethane.

[11] Newell et al., *J. Am. Med. Assoc.*, 135: 760 (1947).

[12] Council on Pharmacy and Chemistry, *J. Am. Med. Assoc.*, 145: 728 (1951).

[13] Longenecker, *J. Am. Dietet. Assoc.*, 27: 185 (1951).

Utensils and Containers as Possible Sources of Toxic Substances in Food

With the possible exception of platinum, all metals are to some extent soluble and corrosive. Their relative solubility can be determined by chemical methods. The question of the amount of a metal which constitutes a health hazard may be very difficult to answer. In some cases solubility is high and a single exposure causes definite illness. Zinc, antimony, and cadmium belong to this class. Zinc is used for galvanizing iron pails and has caused poisoning when the pails were used as containers for lemonade. Cases of antimony poisoning have been traced to the use of inexpensive antimony oxide rather than tin oxide to create opacity in enamelware. In this country, its presence in tin foil to wrap such foods as cheese has been regarded with suspicion, but most metal foils are now made of aluminum. Cadmium has been responsible for poisoning when it was employed to replate the ice trays in mechanical refrigerators or other food containers. Copper and brass are also generally considered undesirable metals for food containers because they are highly soluble in some foods and produce poisonous salts. Tin or chrome plated copper utensils should be replated or discarded whenever the plating wears down to expose the copper.[14]

Lead should not be used in food containers, but it is occasionally present in the glaze on cheap stoneware and enamelware and in old pewter. If old pewter is not polished on surfaces in contact with food, these surfaces become coated with a resistant film.[15]

Other metals which come in contact with food in containers or utensils but which are considered harmless are iron, steel, tin, and aluminum. Although iron may be dissolved to some extent by foods, iron salts from this source as well as those naturally in the foods themselves, are of value to the body. They may have objectionable effects on the color and flavor of certain vegetables, as will be discussed later. Steel is less soluble than iron, and that of the stainless types in particular is little affected by food.[16]

Tin in cans or cooking utensils is plated on a foundation of sheet iron. It is relatively insoluble, but that on tin cans, for example,

[14] Queries and Minor Notes, *J. Am. Med. Assoc.*, 135: 879 (1947).

[15] Queries and Minor Notes, *J. Am. Med. Assoc.*, 125: 684 (1944).

[16] Queries and Minor Notes, *J. Am. Med. Assoc.*, 141: 574 (1949).

may be dissolved to some extent by acid fruits. Solution is accelerated when the can is opened and the contents are exposed to air. Tin salts are tasteless and have never been shown to be harmful, but contact with the iron underneath may change flavors so that one prefers to empty opened cans of such products for storage in more insoluble containers such as glass.

The extensive use of aluminum cooking utensils and the occasional propaganda against them, often sponsored by the manufacturers of competing types of utensils, have stimulated research regarding the solubility of aluminum in foods and the harmfulness of its salts. Aluminum is attacked readily by bases such as soda in solution, but it is only slightly corroded by acids of the strength found in most foods. Neutral foods remove only very insignificant amounts of metal from these utensils. The dark stain which accumulates on the exposed surface of aluminum is iron deposited from water or food, or iron which exists as an impurity in aluminum and is left behind as the surrounding aluminum is dissolved, or aluminum oxide. When fruits are cooked in such a pan, this coating is removed by their acids. Wrought aluminum is more highly purified than the cast variety and resists corrosion better.

The status of reliable opinion on the question of harmfulness of the small amounts of aluminum dissolved by foods cooked in contact with it is summarized in the following statement from the Council on Foods and Nutrition of the American Medical Association.

> Periodically rumors are circulated to the effect that foods cooked in aluminum cooking utensils are deleterious to health because of injurious substances imparted by the vessel. Thus it becomes necessary to again call attention to pertinent facts about aluminum.
>
> Aluminum abounds in the earth's crust and is widely distributed in nature, being present in a wide range of edible plants. Undoubtedly man has ingested small quantities of aluminum daily since he came upon earth. Aluminum compounds are also important and useful therapeutic agents.
>
> The possibility that aluminum utensils can impart injurious agents to the foods cooked in them has been extensively investigated. Up to the present time there has been no cogent scientific evidence indicating that the minute traces of aluminum that may be imparted to food in the process of cooking are in any way injurious to the consumer. As for the rumor that the use of food prepared in aluminum cooking utensils is a

factor in the causation of cancer, it may be added also that there is absolutely no scientific basis in support of this view.

In view of these facts it is the opinion of the Council that the use of aluminum cooking utensils is in no way injurious to health.[17]

Enamelware of the better grades is corroded only by relatively strong acids. The white product is said to be most readily attacked because its color cannot be preserved when it is baked long enough to make it as resistant as the darker kinds. It is also less durable than the others because the coating must be heavier. The thinner the enamel, the more it resists impacts and sudden changes in temperature. Enamelware which has been chipped so that the underlying iron is exposed is undesirable for cooking or holding at least such foods as have flavors and colors which are unfavorably affected by this metal. Neither the possibility of swallowing small chips of enamel nor the dissolving of metals used in making the enamel appears to be hazardous.

Formulas for vitreous enamels vary extensively, but in the main the constituents appear to contain metallic silicates. Metallic oxides are employed to impart desired colors such as cobalt for blue, cobalt and manganese for violet, copper and chromium for green. Lead and arsenic formerly enjoyed wide use, but for kitchen utensils have to some extent disappeared. Theoretically these enamels contain poisonous substances, but practically chemical injuries are not to be anticipated from any proper usage of these utensils or from the ingestion of small flakes of enamelware. High insolubility even in gastrointestinal juices assures comparative safety. Occasional claims are made of mechanical injuries from the cutting and irritating action of enamel flakes much akin to ingested glass fragments. As a rule such claims are without merit. Large scales such as might nick the esophagus are likely to be detected in the mouth. The mass action of a few small particles is so slight as to make harm improbable. The importance formerly attached to this class of foreign bodies in the gastrointestinal tract, and particularly small fragments, probably exaggerated the extent of any real harm produced.[18]

Pyrex and other glass containers are insoluble in foods. The solubilities of materials used in equipment in contact with food are summarized in Table VII.

[17] "The use of aluminum cooking utensils in the preparation of foods," *J. Am. Med. Assoc.*, 146: 477 (1951).

[18] Queries and Minor Notes, *J. Am. Med. Assoc.*, 115: 798 (1940).

Table VII. Solubility of materials used in food utensils and equipment

Material	Relative solubility in foods
Allegheny metal (Fe, Mn, P, S, C, Si, Cr, Ni)	Practically insoluble
Aluminum	Practically insoluble
Brass (Cu, Si, Zn)	Somewhat soluble. May be undesirable
Copper	Only slightly soluble in absence of air. In presence of air, undesirable particularly with acid foods
Glass (Pyrex)	Practically insoluble
Iron	Soluble, particularly in presence of acids
Monel metal (Cu, Ni, Fe, Mn, C, and Si or Al)	Slightly soluble
Nickel	Relatively resistant
Nickel silver (Cu, Ni, Zn)	Slightly soluble
Pewter (Sb, Sn, Pb)	Slightly soluble, especially if it contains lead
Silver	Resistant except to foods containing sulfur
Stainless steel (composition variable)	Practically insoluble
Steel, ordinary low carbon	Soluble to varying degrees
Stoneware	Insoluble except for inexpensive types containing lead in the glaze
Tin	Somewhat soluble in fruit and vegetable acids in the presence of air. Practically insoluble in closed containers
Zinc	Soluble. Should not be used in contact with food

PLANNING FOR HIGH SANITARY QUALITY IN THE DAY'S MEALS

The attainment of high standards of sanitary quality in meals is not altogether a matter of the condition of the raw materials and their preparation, because contamination may occur in the course of holding and serving the foods. The following precautions should ensure wholesomeness under most household conditions.

Precautions regarding the Health and Sanitary Standards of the Persons Who Handle Food:

1. Always wash hands with soap and warm water before touching food and dishes. Avoid handling cooked food with the hands.

2. When suffering from a cold or other infections which can be transmitted by food, do not handle dishes or food without adequate

sanitary practices. Always wash the hands after contact with face or handkerchief. Avoid sneezing or coughing near foods. Persons with infected pimples or boils, or diarrhea, should exercise special precautions when preparing food for the family and should never handle food for public consumption. Be especially careful to prevent contamination of foods after they are cooked, of foods to be eaten without cooking, and of serving dishes.

3. Never return a tasting spoon to food without washing it, and do not lick the fingers.

4. In refilling cups or glasses, never allow the container from which the liquid is poured to touch rims.

Precautions regarding the cleansing of food and utensils:

1. Thoroughly wash or pare all fruits and vegetables, especially any which may carry spray residues or are to be eaten without cooking.

2. Insist upon sanitary dishwashing. This means thorough cleansing in soapy water or water containing a suitable washing powder, rinsing in water not lower than 170 degrees F. (77 degrees C.) in temperature, and either storing in a clean place for air drying, or wiping with sanitary towels and storing in a clean place away from dust, insects, and animals. It is safest to discard chipped dishes because the unglazed portions are porous.

Precautions regarding Storage Temperatures for Perishable Food:

1. Store perishables, especially foods high in protein such as eggs, milk, meat, or mixtures containing them, at low temperatures (not above 50 degrees F. [10 degrees C.], preferably lower). Put freshly cooked custards and similar foods into the refrigerator for cooling if they are not to be eaten within an hour. Leftover meats or meat soups should also be put in the refrigerator rather than left at room temperature for cooling. Do not buy custard-filled products, such as éclairs or cream puffs, unless they are known to be freshly made.

2. Buy ground meat only when freshly ground and preferably when it is to be used after only a few hours in a cold refrigerator. Otherwise freeze it or buy in the piece and grind just before use.

3. Eat or cook frozen foods promptly after complete thawing (exception: canned foods accidentally frozen will keep if the can does not leak).

4. For picnics and lunch boxes, keep foods containing eggs, such as potato salad, salad dressings, custards, and sandwich fillings, and meat or gelatin cool until eaten. If this is not possible, and the time of holding is more than 2 to 4 hours, it may be safer to eliminate these foods from the menu.* In preparing sandwiches for teas, etc., always refrigerate those containing cheese, egg, or meat filling. This is particularly important if the bread has been dampened.

Precautions regarding Sterilization or Pasteurization:

1. Cook all ground meat and pork to at least a medium-done stage (160 degrees F., 71 degrees C.).

2. Buy pasteurized instead of raw milk if it is available. Otherwise heat it to at least 165 degrees F. or use evaporated or dry skim.

3. In canning, process all nonacid foods (most vegetables and meat) in a pressure cooker.

Precautions regarding the Tasting of Foods of Doubtful Sanitary Quality:

1. Discard, without tasting, the contents of tin cans which bulge or glass jars which spurt on loosening the cover.

2. Risk neither tasting nor serving food of questionable appearance or odor.

Precautions When Eating Away from Home, If Sanitary Standards Are in Doubt:

1. Choose pasteurized milk served in the bottle, freshly cooked foods, especially eggs or meat, fresh fruits with the skins on to be removed before eating, canned foods opened to order.

2. Avoid ready-made egg or meat sandwiches standing on the counter and custard-type desserts.

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* The time that it is safe to hold perishable foods without refrigeration varies with the temperature and the nature and degree of contamination.

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CHAPTER 4

PALATABILITY IN THE APPRAISAL OF FOODS

The sensory properties of foods.

The kinds of sensory properties affecting the palatability of foods.

Intensity of sensations from food in relation to palatability.

Factors affecting individual capacity to experience the sensory properties of foods.

The measurement of the sensory properties of foods.

Relation of sensory properties of food to its acceptability.

Factors besides sensory properties which affect the acceptability of food.

The origin of food preferences.

Developing wide acceptance of foods.

Advantages to the individual of learning to accept a wide variety of foods.

The measurement of food acceptance.

Planning for high food acceptance in family meals.

Palatability, often spoken of as *eating quality*, may be defined as the relative acceptability or appetite appeal of a food. Having an appetite for food differs in nature from being hungry. Hunger is associated with contractions of an empty or almost empty stomach. Since people without stomachs experience hunger, there must be some other physiological basis also, possibly lowered blood sugar or secretion of a hunger hormone. Hunger produces discomfort, irritability, and restlessness, and stimulates the seeking of food. It develops more rapidly after physical exercise than after sedentary work. Most people who eat three substantial meals a day seldom notice hunger, and those who habitually omit a meal may develop indifference to it. It is now believed that babies on strict feeding schedules may develop into children who dawdle over their food because their sensitivity to hunger sensations has been dulled.

Appetite, in contrast to hunger, is a reaction to present or remembered stimuli from food rather than an internal physiological state. It may develop when the stomach is full as well as empty, as everyone has experienced when a particularly attractive dessert is served at the end of a large meal. It produces a flow of digestive

juices in both mouth and stomach. Appetite is more discriminating than hunger—hunger may be so intense that a starving person will consume materials which are not only unappetizing but lacking in any nutritive value and hence not foods at all.

The palatability or eating quality of a food has two aspects: (1) the sensory properties or stimuli coming from the food, and (2) the attitude of the eater toward the food.

THE SENSORY PROPERTIES OF FOODS

Although we all have food preferences, we are not in the habit of observing the sensory properties of food discriminately. Thus most of us get our satisfaction from the act of eating rather than from sensations produced by the foods that we eat. Limiting our awareness of food in this way is like listening to music in which one is scarcely conscious of more than a vague series of pleasant sounds. Cultivating appreciations in the field of food can increase the pleasures of anyone and may have professional value for many who read this book. Food preparation is an art as well as a science. Connoisseurs of food are trained and experienced observers of the sensory properties that it offers. To them, tough or soggy pastry is as inartistic as a badly painted picture, and some of the bizarre combinations of ingredients recommended in popular magazines as deficient in good taste as a gaudy calendar.

There are perhaps three basic cuisines (styles of cooking) in the world: (1) the *French* which uses seasonings to bring out the flavors in foods, (2) the *Chinese* which uses seasonings to change the natural flavors, and (3) what might be called the *naturalistic* which conserves the original flavors of the raw foods and makes much less use of added seasonings. The first two systems developed when methods of food preservation were very primitive, and most foods which deteriorate rapidly were inferior by our standards. Added flavors were needed to compensate for this damage, and no doubt much of the traditional use of spices and herbs was for the purpose of masking unattractive flavors. Our superior cold and freezing storage facilities, in particular, allow retention of natural flavors over long periods and often make added flavors unnecessary, though they still have a place in extending variety.

As in judging the products of other arts, the palatability of foods may be evaluated on the basis of the kinds, quality, and intensity of sensory impressions involved. The musician utilizes stimuli af-

fecting but one sense organ, that of hearing, but the cook may stimulate as many as five or six sense organs, the number depending upon the classification followed.

The Kinds of Sensory Properties Affecting Palatability of Foods

The principal sensory properties of foods are:

1. Odor or aroma.
2. Flavor which is a combination of taste and odor.
3. "Mouth feel."
4. Appearance.
5. Temperature.

Odor or Aroma and the Palatability of Food

The stimuli for smell are air-borne gases or finely divided solids which are perceived when they come in contact with olfactory receptors in the nostrils. In common speech, there are no names for smell qualities apart from those of objects. Thus we speak of the smell of particular fruits, spices, burning materials, etc. Attempts have been made to classify odors. One such classification divides them into four groups: fragrant or sweet, acid or sour, burnt, and caprylic or goaty.[1] This is said to be the order of preference by most people when the sensations are strong. Most natural odors are considered combinations of different intensities of the basic four.

Flavor and the Palatability of Food

Flavor, which we usually call taste, is a composite sensation made up of odor and taste. The stimuli for taste itself are certain substances dissolved in the oral fluids so that they come in contact with receptors located, for the most part, on the tongue. It is believed that there are only four simple taste sensations. They are described as:

1. Sour or acid, produced by hydrogen ions.
2. Salty, produced by some salts, such as NaCl, KCl, NH_4Br, NaI.
3. Bitter, produced typically by alkaloids, such as quinine, but also some salts.
4. Sweet, produced by sugars, saccharin, and some other organic compounds such as glycerol and certain amino acids.

Taste buds that respond to sour stimuli are located for the most part along the sides of the tongue. Those responding to salt are

[1] Crocker, *Flavor*, McGraw-Hill Book Co., New York (1945), p. 12.

concentrated on the sides and tip. Sweetness is experienced mostly at the tip, and bitterness at the base.

Many sensations which are really caused by odors are commonly attributed to taste. "Tasting like coffee" does not differentiate between tea, coffee, and quinine, when one has a cold which closes the nasal passages. The confusion between taste and smell arises because odors may reach olfactory centers when the food is entering the mouth or from the rear while it is being swallowed. Deliberate sniffing is necessary to get the full effect of odors. Colds do not affect capacity to taste, in the correct meaning of the word, but they do prevent smelling. Our capacity to smell is more sensitive than our capacity to taste because a much smaller concentration of the material produces a recognized sensation. This sensitivity added to their great variety and complexity makes odors especially important in food flavors.

Flavors or tastes in combination may have marked effects on each other. Thus sodium chloride—ordinary table salt—reduces sourness of acids and increases sweetness of sugars. Sugar reduces saltiness and sourness.[2] We have already mentioned the use of herbs and spices to cover up undesirable flavors.

"Mouth Feel" and the Palatability of Food

The many sensations included under this term are responses to both chemical and physical stimuli. The former, usually called *common chemical sensations*, react on the mucous membranes of the mouth and nose. They are produced by mildly irritating chemicals and are described by such terms as astringent, biting, hot (for example, peppers or spices), and pungent. When these stimuli are very intense, they may produce watering of the eyes, sneezing, coughing, or choking.

The much-publicized seasoning, monosodium glutamate (MSG for short), has all four taste qualities and is said to produce its effect of intensifying flavors by stimulating the taste buds. This effect is especially pleasurable in meats and mild vegetables. In addition, MSG has a tingling effect in the mouth and gives a lasting and satisfying element to flavor; both effects are probably common chemical sensations.[3]

Physical stimuli causing variations in "mouth feel" cover a wide

[2] Fabian and Blum, *Food Res.*, 8: 179 (1943).

[3] Crocker and Sjöström, *Food Res.*, 13: 450 (1948), and *Food Technol.*, 2: 317 (1948).

range of texture qualities described by such terms as gritty, lumpy, crisp, smooth, liquid, soft, hard, stiff, thick, thin, coarse, fine, tender, tough, moist, dry, soggy, juicy, heavy, light, mealy, grainy, greasy, etc. These stimuli are perceived by contact (touch) and are sometimes divided into pressure and muscle sensations. The pressure receptors are located on body surfaces and differentiate weights of contact. Muscle, also called kinesthetic, sensations are received by end organs deep-seated in muscular tissue. They create awareness to movement. The pressure and muscle sensations together permit us to make the discriminations listed as differences in texture.

Appearance and the Palatability of Food

The stimuli for visual sensations are light waves impinging on the retina. Visual appeals that foods make are related to form or shape, size, design, and color. Of these, color is especially important in relation to palatability. For human beings, eye appeal exceeds dependence on taste or odor. Over-all appearance may determine acceptance or rejection without a trial tasting; consequently it deserves much consideration in food preparation.

Temperature and the Palatability of Food

Temperatures are experienced by warm and cold end organs scattered over body surfaces. Psychological zero, or lukewarmness, is a temperature slightly below that of the body interior. In the direction of either more or less heat, extremes cause pain. The exact temperatures at which such descriptive terms as warm, cold, hot, are to be applied vary with both the remote and recent history and experience of the individual.

Temperature affects the intensity of food flavors. Crocker says that tasting is most accurate when food is at body temperature or slightly below. Thus hot tea with lemon does not taste sour until it cools. The acidity receptors lose sensation at temperatures above 100 degrees F. (38 degrees C.). This is also true of saltiness, but temperature has a less noticeable effect on sweetness and bitterness.

Odors become more pronounced as the temperature of a food is raised, but as heating is continued or as hot food stands they diminish. This is because the food particles producing smell are volatile. Thus the more coffee odor there is in the room, the less coffee flavor in the pot. Towards the other end of the temperature scale, odors and hence flavors diminish. Cold drinks and frozen desserts require much more added flavoring than those consumed at warm

temperatures. Menthol as a flavoring gives a feeling of coolness. Apparently it sensitizes the temperature receptors so that they exaggerate actual coolness.

Intensity of Sensations from Food in Relation to Palatability

Not only difference in the qualities of sensations from food as discussed above, but the intensity of those sensations affects eating quality. A taste, odor, or almost any other stimulus may be so intense that it is painful. However, mild degrees of pain may be considered pleasant, as in eating very sour pickles or drinking hot or carbonated beverages. Also some flavors, such as those of onion or garlic, may be very acceptable when dilute but unpleasant when concentrated. One of the major abilities that makes for skillful creative food preparation is the ability to achieve just the right intensity of flavors.

Factors Affecting Individual Capacity to Experience the Sensory Properties of Foods

We have pointed out that discrimination in relation to the palatability of foods can increase the enjoyment of the individual eater. It is of professional significance for experts in food production, food manufacturing, and food preparation for the public. The BHNHE and other researchers have found that the most all-around satisfactory way to test foods for flavor, texture, and other properties is to serve samples to expert human judges and compare verdicts.

Are all people equally discriminating judges? Is each of us equally competent under all circumstances? It is common knowledge that persons differ in their capacity to differentiate color and sound qualities. People vary also in their capacity to experience taste and odors, some not being at all aware of those which are recognizable or very potent to others. In a test of the taste sensitivity of 64 persons by the BHNHE, it was found that some individuals failed to identify the taste quality (salt, sweet, sour, or bitter) entirely. The threshold, or level of concentration, at which a taste quality was evident, varied markedly. The more discriminating persons were more likely to duplicate their judgments of the taste of a particular food such as bread.[4] These individual differences in sensory discrimination, like

[4] King, *Food Res.*, 2: 207 (1937). Also, Knowles and Johnson, *Food Res.*, 6: 2 (1941).

others such as those for color and sound, are undoubtedly primarily a result of inheritance or training or both. Some other factors which may cause differences are sensory fatigue, smoking, state of health, attentiveness, age, and possibly sex.

Innate differences in capacity to taste and smell have been proved by tests with the chemical phenyl-carbamide which was bitter to most of those who could taste it and not perceptible at all to others, and with a particular verbena which had a pronounced odor to some and could not be smelled at all by others.[5] Thus individuals may be born taste- or odor-blind just as some are color-blind or completely lacking in a sense of pitch. In fact, few, if any, judges are equally proficient in testing all food flavors. On the other hand, there seems to be no question but that attentiveness and training can develop discrimination in most of us. Careless persons even when endowed with high sensitivity do not make consistent judges of food.[6] Nor can good judging take place when there are interruptions or distractions.

Sensory fatigue experienced by all of us in our eating is a problem to food judges. Our receptors become adapted to a particular stimulus which makes its intensity appear to decrease as exposure is prolonged. This is particularly noticeable with odors. The last bite of a serving of food is not likely to have the same intensity of flavor as the first. Probably many have noticed that one must move a piece of candy around in the mouth if it is to stay sweet. In one study, it was found that continuous sniffing of bread from 1 to 4 minutes was sufficient for most judges to lose perception, but the rate varied with individuals.[7]

Professional judges may attempt to prolong their capacity to differentiate these properties of food by refraining from swallowing the food, by rinsing the mouth with distilled water between test bites, and by rest periods. Adaptation to one stimulus does not ordinarily affect others, but smoking may dull taste and smell and should probably follow rather than precede a meal if one is to eat with sensory discrimination.[8] Perhaps strong alcoholic beverages have the same effect.

State of health, particularly respiratory infections or allergies, may also interfere with sensory response to food. Some tests have shown

[5] Blakeslee, *Sci. Monthly*, 41: 72 (1935). Also Blakeslee, *Science*, 81: 504 (1935).

[6] Lowe and Stewart, *Food Technol.*, 1: 30 (1947).

[7] Eppright, *J. Am. Dietet. Assoc.*, 23: 579 (1947).

[8] Boelcke and Rauth, *J. Chem. Educ.*, 9: 186 (1932).

that age and possibly sex may likewise be factors in relation to particular if not general discrimination in this field. In one test young people rather than middle-aged were better judges of relative sweetness and saltiness, but not of acidity.[9] In another, high school students were more discriminating judges of the flavor of oranges than adults.[10]

The Measurement of the Sensory Properties of Foods

Methods which have been used to measure differences in sensory qualities of foods include sensory ratings by human judges, chemical tests, and physical tests. Thus samples of meat may be ranked as to relative tenderness by chewing comparisons, by physical measurements with an instrument devised to measure the force required to "shear" or cut pieces of the meat, or by chemical determinations of the relative amounts of collagen and elastin, two proteins which have been shown to affect this property of meat.

Judges who are sufficiently endowed by nature and equipped with training to duplicate their ratings on different sets of samples or on different days are probably much fewer than has been assumed. However, most experimenters agree that chemical and physical tests alone are not adequate to give the required information.[11]

Relation of Sensory Properties of Food to Its Acceptability

The sensory properties of food as a matter of everyone's experience are important in their effect on its acceptability. Observation of the behavior of others reveals positive or negative responses to a particular sensation or to combinations of sensations that may lead, on the one hand, to capacity consumption, or, on the other, to complete rejection, with the possibility of any intermediate degree of acceptance. Thus children drinking reconstituted evaporated milk may accept it when it is cold and reject it when it is hot.[12] Little children are particularly resistant to dry or tough textures and dislike strong flavors.[13] Most people find vegetables more ac-

[9] Baten, *Food Technol.*, 4: 277 (1950).

[10] Harding and Wadley, *Food Res.*, 13: 6 (1948).

[11] Boggs and Hanson, in *Advances in Food Research*, edited by Mrak and Stewart, Academic Press, New York, 1949, Vol. II, p. 220.

[12] Hollinger and Dodd, *J. Home Econ.*, 40: 507 (1948).

[13] Lowenburg, *J. Am. Dietet. Assoc.*, 24: 430 (1948).

ceptable when they are prepared by methods which retain bright, fresh colors. Methods of preparation of all basic foods as discussed in this book will emphasize the attainment of sensory qualities which are highly acceptable either to the connoisseur or to the majority.

High qualities of appetite appeal in the foods themselves have several values. They can influence the kinds and amount of foods chosen. If homemakers used more skill in preparing the foods most needed in larger amounts, vegetables for example, rather than desserts, this alone would help improve nutrition in the family. Also high standards of preparation and skillful stretching of flavors of relatively expensive foods, such as fruits and meat, make it possible for the eaters to enjoy low-cost meals.

Besides aiding in stimulating the consumption of the right kinds and amounts of food, palatability has esthetic and social values. Gastronomy, the "art or science of good eating," is an esthetic pleasure that is not in very high repute at the present day. This has not been true at all periods in human history, and there is no valid reason why the temperate cultivation and indulgence of the senses involved in the appreciation of food should not be as respectable as the cultivation of other senses in appreciation of other arts. The standard in all cases should be enjoyment from appreciation of quality, not from the indulgence in quantity, which, in the case of food, is gluttony.

Many homemakers find a pleasant outlet for creative expression in preparing palatable foods. Cookery may be for some persons, of both sexes and all ages, an enjoyable hobby.

It is significant that another definition of gastronomy is the "art of good cheer." Any shared pleasures increase sociability, and good food ranks among the highest of such stimulants. Dining becomes a means of expressing hospitality and friendliness. Indeed, the feeling that "breaking bread" with an outsider creates a bond and sense of personal obligation between host and guest is so ancient in origin that we cannot trace its beginning.

In many contemporary homes, especially urban homes, the dinner hour has become the only period during the day when the family is gathered together. The socializing values derived from an atmosphere of enjoyment on that occasion are inestimable. The contribution provided by the palatability of the food served is worth a reasonable cost in time and money. Frequently, these costs are no more than those for unappetizing dishes.

FACTORS BESIDES SENSORY PROPERTIES WHICH AFFECT THE ACCEPTABILITY OF FOOD

Everyone has observed that a given combination of sensory qualities in a food does not produce the same acceptance by all persons to whom it is served. These differences in reaction are not to an important extent caused by differences in capacity to experience the sensory qualities of the food. In fact, most people have never developed to a high degree their ability to discriminate among flavors, textures, and other qualities of food, and yet they express very definite preferences.

Neither are differences in response to a food altogether associated with its particular sensory properties. True, some flavors, textures, etc., are more generally acceptable than others—for example, the trend toward softer, smoother foods indicates a general preference for these texture qualities. But studies of food habits throughout the world show that almost everything that has any nutritional value, including worms, snakes, and insects, is consumed somewhere. On the other hand, the army found it could serve foods which were highly acceptable with respect to kind and standards of preparation to those responsible for planning, and yet healthy, hungry men would refuse to taste them.[14]

Observations and experiments on the likes and dislikes of both children and adults lead to the conclusion that they are not completely controlled by the nature and intensity of the stimuli received from the food, or by the individual's capacity to experience them. They are attitudes which require another explanation.

The Origin of Food Preferences

From work with young children, we have come to know that, like much of the rest of our behavior, responses to food are learned. They are the products of our experience with food and other people's attitudes toward food. In a general way, the foods we like are the foods we are accustomed to, and our principal inborn reaction to food is a distrust of the unknown—the product which has an unfamiliar flavor or "mouth feel." The major role of the sensory properties of food is to assure us of familiarity. In nursery

[14] Dove, *Food Technol.*, 1: 39 (1947).

schools, observers report that unfamiliar foods are often rejected in the first trial, but that repeated tastings on other days to develop familiarity are usually followed by acceptance or obvious liking.[15] A tendency to reject the unfamiliar, of course, has had survival value for primitive man because examples of *apparently* edible but *actually* poisonous materials occur everywhere.

Although, by the time they are of college age, individuals give taste more often than other reason for not liking foods, it is probable that not only relative unfamiliarity but prevailing prejudices based on the origin or function of the food are unconsciously involved in many cases. In a study in which students were asked to check foods which they disliked, the most disliked group consisted of buttermilk, brains, liver, oleomargarine, parsnips, eggplant, caviar, hominy, oysters, turnips, rutabagas, and clams. It is well known that a single unpleasant experience (psychological or physiological) may be so associated with a particular food that it is persistently rejected after having been well-established among one's likes.[16]

Developing Wide Acceptance of Foods

Developing acceptance of a wide variety of foods should begin in infancy. The right emotional atmosphere and techniques of introducing new foods are important. Security in parental affection is especially fundamental. Babies normally experience affection and the getting of food at the same time, and the association tends to persist in later years. Mealtime should always be free from tensions and scoldings.

In families, constant table talk about food—likes, dislikes, food values, individual idiosyncrasies—creates a poor atmosphere for development of desirable eating habits in children. Eating should be as casual as playing or sleeping.

Coaxing, bribing, or forcing a child to eat, or even letting him know that it is important to the parent whether he eats a particular food or not, not only defeats attempts to develop liking for the food in question but produces difficult behavior problems. Adults also create eating problems with children by urging consumption of desirable foods because "they are good for you," and using such generally unbalanced foods as sweet desserts as rewards. In fact,

[15] McCoy, Waring, and Kruse, *Gen. Psychol. Monographs*, 22: 4 (1940).

[16] Hall and Hall, *J. Am. Dietet. Assoc.*, 15: 540 (1945).

most people of all ages tend to avoid new foods when told that they are of superior nutritive quality. The low general appeal that this designation has, at least for a new food, was demonstrated during the war when an attempt was made to increase sales of soybean products in a government cafeteria by use of posters with different appeals. Those that made no mention of nutritive value produced more sales than those which did.[17] If reasons are given at all, the most effective are those which make eating recommended foods fit in with the most urgent wants of the individual—health, vigor, good looks, saving money, pleasure in eating, etc. Parents who themselves set a good example by drinking milk and eating the recommended vegetables with obvious enjoyment, usually have little difficulty with their children's eating these important foods.

In general, children tend to eat a large variety of foods and make few rejections when their eating habits have been supervised in a matter-of-fact manner without obvious concern, and when they have been given wide experiences. Mostly liked foods should be served, and only one new food should be offered at a meal, and that in a very small serving, to be repeated within 2 or 3 days so that it will not be forgotten. The observation that young children accept unfamiliar foods more readily than older children should be utilized by giving a wide variety early.

Leftovers should be removed without comment, and "cleaning up the plate" should not be required. Eating should never be forced, and the time at the table should be limited.

Adults who appreciate the importance of nutrition tend to be overconcerned about their children's eating habits. Children grow at different rates at different periods. When the natural slowing down in growth rate begins during the latter part of the first year, relative appetite also diminishes: a healthy child's appetite is the best guide to how much he needs. Omitting part or all of an occasional meal is not harmful. Failure to drink milk for a meal or even for several days will not cause a nutritional deficiency disease or stunt growth.

If appetite is persistently poor or erratic, a medical examination should eliminate possible physical cause. What is eaten should be scrutinized from the standpoint of reducing fat, skimming milk for example, to produce more rapid emptying of the stomach. The effect of between-meal snacks should be considered. If these meas-

[17] Woodward, *J. Home Econ.*, 37: 19 (1945).

ures do not remedy the situation, help from an outside expert—someone with specialized knowledge of child psychology—is probably needed.

Group feeding offers one of the best situations for enlarging food acceptance. About 20 per cent of our meals are eaten outside the home. School lunches, college dining halls, military messes, and some community eating establishments offer the trained dietitian an opportunity to develop interest in more kinds of foods and more nutritious foods. In the first place, people tend to eat what is put before them. When milk and fruit juices are as available as soft drinks, they compete successfully. Strategic location of foods also affects choices—putting less needed desserts at the end of the line in a cafeteria reduces their consumption. In the second place, we tend to imitate others in food choices, and, when those with different preferences eat together, their likes are communicated to the group. The choices of persons with prestige in the group are particularly influential, for example, teachers, older students, etc., in the school situation.

Morale in other groups, as well as in the family, has a great deal to do with food acceptance. When relationships are good and the atmosphere free from tensions, even unattractive food may be eaten with gusto. On the other hand, when the group has poor morale or when individuals are worried, insecure, or frustrated, the cause may have nothing to do with food, but the reactions may take the form of complaints about the meals or rejections of dishes which have been eaten freely. In institutions such as college dormitories, necessary restrictions plus the adjustments to being away from home commonly generate unconscious irritability which is directed at the food. Complaining about food is socially acceptable in such groups, whereas criticizing one's roommate, teacher, or other college personalities may not be.

Educators might have more influence in changing food habits if they adopted teaching procedures which have been proved effective. For the most part, these technics involve active participation of the learner in discussion, in making group decisions to try the recommended procedures, and in group planning, preparing, and eating of the recommended foods.[16]

Can individuals change their own attitudes toward a food? Anyone who analyzes his own reactions to food can usually recall ex-

[16] Radke and Caso, *J. Am. Dietet. Assoc.*, 24: 23 (1948).

amples of foods which he at one time disliked but now relishes. Under experimental conditions, it has been demonstrated that an original rejection of evaporated milk on the part of children and adults of a wide range of ages can be changed to a neutral attitude or a positive liking by creation of the right attitudes, that is, desire to like it, and repeated trials.[19]

Advantages to the Individual of Learning to Accept a Wide Variety of Foods

Learning to like most foods is desirable:

1. To help ensure a good state of nutrition.
2. To increase adaptability.
3. To enlarge satisfaction in eating.
4. To increase effectiveness in influencing the food habits of others, whether in a profession dealing with food, or among our families and other associates.

Food Acceptance and Good Nutrition

In this book we emphasize the importance of nutritive quality as a criterion in the selection and preparation of foods. But most people actually base their choice of food on its appetite appeal. Some go so far as to maintain: "Eat what you like and you need have no further concern about your food." Is this a safe rule? Are the sensory qualities of foods and our food preferences sufficiently related to the meeting of body needs to ensure optimum nutritional health? If we lack an essential nutrient, does our appetite lead us to eat the appropriate foods?

It is obviously true that the human race has survived without scientific knowledge of nutrition, and that individuals who never heard of a vitamin have lived to a vigorous old age. But it seems certain that the members of no large group have ever been equally well-nourished, and that few, no matter how vigorous and gifted with longevity, might not have had more of these qualities if they had eaten according to scientific nutritional standards throughout their lifetimes. In fact, there may well have been tribal groups which died out because they had an inadequate pattern of eating.[20] We do not have detailed knowledge of the foods consumed by earlier

[19] Hollinger and Roberts, *J. Home Econ.*, 21: 923 (1929).

[20] Mead, *J. Am. Dietet. Assoc.*, 25: 677 (1949).

generations in any country, but it is certain that, during the last hundred years in the United States, average consumptions of vitamin A, vitamin C, and calcium have increased from very deficient levels. During the same period, before the program for enriching white bread and flour, the average intake of iron and thiamine diminished markedly and below a safe level, especially in the case of the latter.[21] Both longevity and the average state of health have already improved to a high level with these developments, and there is reason to believe that further gains are possible, if we more generally apply the nutritional science that we now have.

Certainly there can be no question but that some people who could afford to buy adequate food suffer from nutritional deficiencies. Persons have been known to develop scurvy when fresh fruit was readily available. No specific craving guided them to more adequate choices.

Whatever may have been the success that attended food choices based on casually developed preferences in the past, for new reasons these are unsafe guides today, and they should be supplemented by an intelligent appreciation of the nutritive quality of individual foods. When the food supply was selected from plant and animal materials which were consumed without much fractionation and refining, following custom would usually ensure a fair degree of success in attaining a good state of nutrition. But, today, it has become usual to rely heavily upon milled cereals and refined sugars and fats, all very unbalanced foods and foods which do not satisfactorily balance each other's deficiencies.

Though children and adults whose eating habits are the product of learning under such influences as we have outlined fail to have trustworthy appetites, the question is still raised whether we are born with instinctive appetites which would lead to optimum nutrition if they were left alone. Most discussions of this subject refer to an experiment in which a number of *infants* of *weaning age* were allowed *free choice* among a variety of *simply prepared, natural* foods.[22] Some of these children followed this regime for as many as 6 years and during that period grew normally and exhibited other signs of good health. Uncritical readers have assumed that this proves that all children would choose nourishing combinations of

[21] Wilder and Keys, *J. Am. Med. Assoc.*, 120: 529 (1942).

[22] Davis, *Can. Med. Assoc. J.*, 41: 257 (1939). Davis, *Am. J. Diseases Children*, 36: 651 (1928).

foods if left without adult control, but they fail to take into consideration these elements in the experimental situation:

1. Only simply prepared foods in natural (unrefined) forms were offered.
2. There was no opportunity to "catch" bad adult eating habits.
3. Even six years is far from a lifetime.

Contrary to the mistaken interpretation of many popular writers, and psychologists who should know better, who have read about this experiment, it does not afford the slightest evidence that self-selection at the ordinary family table would result in a good state of nutrition in children.

Experiments on selection among various types of food materials by animals, which might be expected to have more reliable "nutrition instincts" than man, show that their capacity to choose successfully has limitations. A comprehensive review of many of these investigations carries these conclusions:

1. Appetites are often fickle and unpredictable.
2. Appetites may be trivial in origin.
3. Nutrition based on appetites is not universally successful.
4. Individual animals vary in their ability to make choices that will improve nutritional status.
5. Factors affecting human appetite may be expected to be more numerous and complex than those affecting the appetites of animals.
6. From the evidence, self-selection of diets appears to be inferior to scientific evaluation of diets for maintenance of good nutrition.[23]

For most of us, eating the foods which will produce good nutrition requires learning to like some of them. Although few foods are indispensable for good nutrition (probably milk meets this qualification), choices are often limited, so that rejection of one food in the day's meals may make the difference between meeting all body needs adequately and failing to meet one or more of them. Milk, citrus fruits, tomatoes, greens, carrots, and liver are examples of foods of sufficient nutritional importance to deserve special consideration here. Vegetables as a class, and especially those with marked flavors, have the lowest rate of acceptability of all food groups and should receive particular attention on account of their importance in preventing common deficiencies.

[23] *Nutrition Revs.*, 2: 199 (1944).

Food Acceptance and Personal Adaptability

With sufficient knowledge of food values, nutritional requirements may be met by choosing meals from a very small number of foods. But in the modern world everyone eats some meals away from home, and restricted food preferences are certain to inconvenience the person who has them and to annoy others. One of the elementary rules of etiquette requires that we eat at least part of each food served as a courtesy to the hostess. Being interested in new foods or new methods of serving them is a social asset. Rigidity in food likes can be a major cause of friction in marriage.

Furthermore, wars, and their aftermaths of inflation, by altering normal food supplies and prices, force most of us to change long-established patterns of eating over relatively short periods. Economical or nutritionally desirable foods, now consumed by substantial numbers, were often slow to be accepted—for example, oleomargarine and dried skim milk. It took 250 years for Europeans to adopt the potato. Other new or little used foods could be readily supplied by the market with advantages to health or pocketbooks if public taste was not so conservative, for example, less familiar varieties of fish, soya products, and curly kale.

Food Acceptance and the Enjoyment of Eating

An experimental attitude toward food, which leads one to welcome opportunities to eat new foods and to develop wide appreciations of food, carries with it the satisfying cultural values associated with this approach to any of the arts. In fact, relative freedom from prejudices against particular foods and an experimental attitude toward new foods are more characteristic of persons of wide cultural background than of those of limited experiences. A critical but experimental attitude towards food rather than one which limits appreciations of methods and materials to the familiar distinguishes cosmopolitanism from provincialism at the table.

Food Acceptance and Influencing Others to Develop Good Food Habits

Those of us who hope to use our knowledge of nutrition to influence the eating habits of others, in the home or out of it, can do so most effectively when we ourselves set an example of generally eating all foods, especially those to be promoted for their nutritive value. And finally, especially for the student of home economics, an

adventuresome attitude toward new foods and the conscious exercise of discrimination in relation to their sensory qualities, rather than a fixed set of likes and dislikes, have professional as well as personal values. The range of food choices that the modern market presents to consumers is the greatest in history and enlarges every day. Certainly those whose work involves guidance of consumption should themselves have broad and growing appreciations.

The Measurement of Food Acceptance

The measurement of the relative acceptance of palatability is attempted in two ways: (1) obtaining the judgment of experts and (2) testing the preferences of a sample of the public for whom the food is intended. Measures of consumer preferences are, of course, of great importance in the food industries. The agricultural experiment stations which develop and promote new varieties of fruits and vegetables as well as new kinds of plant and animal products are also concerned with them.

The judgment of the connoisseur type of expert may have little validity in relation to marketability of a particular food. It is primarily useful in estimating product appeal for a limited group or in raising the level of group taste.

The broad demand for the measurement of actual consumer preferences has led to the development of three major technics: (1) summarizing market data on what these consumers buy, (2) surveying consumer opinions about products of different quality, and (3) setting up experiments designed to test these preferences on the spot.[24] The first problem in each case is that of obtaining a representative sample of consumers, because it is seldom feasible to include the entire group of interest to the investigator. Interpreting market data may be difficult because the extent to which purchases are influenced by price, advertising, or other factors is unknown. Unless questions are skillfully devised and presented, they may not reveal the true feelings of those of whom they are asked. An experimental situation is likely to be so rigid with respect to time and place that it is impossible to obtain subjects who are sufficiently representative. However, progress in this field in recent years has been substantial, and future findings will doubtless con-

[24] Morse, in *Advances in Food Research*, edited by Mrak and Stewart, Academic Press, New York, 1951, Vol. III, p. 385.

tribute much to putting food processing on a more scientific foundation so far as meeting consumer preferences is concerned.

PLANNING FOR HIGH FOOD ACCEPTANCE IN FAMILY MEALS

We have seen that food acceptance depends both upon the sensory properties of the foods and the experience, past and present, of the eater. High food acceptance at family meals depends upon (1) planning and serving interesting combinations of food which meet high standards of preparation and service, and (2) maintaining a psychological atmosphere that is favorable to accepting what is served.

Attaining High Standards of Palatability in Family Meals

Even when the raw materials for a meal are of high quality, the meal as consumed may be unpalatable. Interesting combinations of dishes and high standards of preparation and service are essential for successful meal planning.

Making Interesting Combinations in Menu Planning. It is not necessary or desirable that menus be planned according to conventions. Lamb, peas, and mint jelly provide a combination of flavors that many people like, but lamb may be just as appetizing when served with other vegetables and other jellies. Meals may include only one or two dishes and be very palatable. During World War II experiments were conducted to determine whether simplified rations which were highly acceptable could be continued over a long period. It was found that, no matter how well the subjects liked the food, or how interested they were in trying to eat it, within 2 or 3 days they were unable to eat enough to meet their needs, and work suffered. On the other hand, some of us like exactly the same breakfast day after day.

By variety, we do not mean the sampling of almost the entire larder for a single meal, still a custom in some communities for guest meals. This practice makes attractive table setting impossible, cuts down the variety for other meals, increases leftovers, overstimulates the appetite for some meals, and creates monotony for others, and increases labor. Desirable ways of securing variety are:

VARIETY IN FLAVORS. Do not repeat foods in the same meal. Example: celery soup and Waldorf salad.

Have leftovers appear in another form and preferably on another day. Example: spinach soufflé or croquettes from leftover spinach.

Do not choose only foods that have bland flavors for a meal. Example: macaroni and cheese, plain muffins, and custard. Do not serve more than one strong-flavored food, such as onions, sardines, salmon, mackerel, or Limburger cheese, in the same meal.

Do not let pronounced tastes such as acids and sweets dominate a meal too much. High seasonings and pronounced flavors are usually most appreciated when used sparingly.

Variety in Textures. Include some hard and some soft foods in a meal so that the amount of chewing required will be varied. Example of a meal requiring too much chewing: creamed dried beef on toast, celery and cabbage salad, fresh fruit cup, coconut macaroons.

Variety in Color. Apply principles of color harmony in planning the menu, especially in relation to the attractiveness of foods served in the same course. Example of a meal monotonous in color: creamed fish, mashed potatoes, cauliflower. Example of a meal with clashing colors: salmon loaf, tomato salad, buttered beets. Furthermore, since decorations and linen or place mats are part of the whole artistic effect, it generally gives greatest appeal to plan a color scheme that includes their effects as well as that of the food.

Variety in Methods of Preparation. Have some cooked foods and some raw foods, and vary the methods used in cooking. Example of a meal containing too much fried food: French fried potatoes, fried scallops and doughnuts.

It is desirable that some foods in the meal be served hot, and others cold. Even in hot weather, to have at least one hot dish or drink is preferable to having none, because it stimulates the flow of digestive juices.

Do not serve a food always prepared in the same way until it becomes monotonous. Potatoes may be prepared in fifty ways. Cabbage may be served raw, creamed, scalloped with cheese, boiled with carrots, etc. It is not necessary to have variety for its own sake, however. If the family enjoys baked potatoes five times a week, there is no reason why they should be prepared five different ways instead.

Meeting High Standards of Preparation and Service. High standards of preparation of food are the subject of much discussion in this book and need not be considered further here. The way in which the food is served is also important. Hot foods should be

served hot, and cold foods should be served cold. Temperature actually affects the intensity and quality of taste. The preparation of foods that cannot withstand holding should be properly timed so that they can be consumed promptly. This applies especially to vegetables.

The artistic appearance of the table and its appointments contribute much to the attractiveness of a meal. Absolute cleanliness and neatness are minimum essentials.

Finally, it should be repeated that scientific eating may be enjoyable. Restricting the size and frequency of serving of rich pies, sweet cakes, and similarly unbalanced foods is all that is necessary in most cases to make room for the essentials and prevent obesity. As new and better habits of eating supplant the old, the appetite for overrich and oversweet foods often diminishes.

Attaining an Atmosphere Favorable to Acceptance of the Foods to be Served.

TRY TO MAKE MEALTIME A PERIOD OF PLEASANT SOCIABILITY. Reserve discussion of personal or family problems for some other time of day. Do not scold or discipline children at the table. Plan so that all members of the family, especially the mother, can remain seated at the table throughout the meal.

IN GENERAL, MINIMIZE COMMENTS ON THE FOOD OR RESTRICT THEM TO FAVORABLE REMARKS. Adults might well refrain from making even favorable comments about rich desserts, the consumption of which should be limited in the interest of good nutrition.

FOR THE MOST PART, SERVE LIKED FOODS. Unless the family as a whole has an experimental attitude toward unfamiliar foods, introduce only one new food at a meal, but repeat it within a few days. Give only small first servings of new or less acceptable foods. Do not comment on failure to eat everything on the plate or withhold dessert.

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CHAPTER 5

ECONOMY IN THE APPRAISAL OF FOODS

Labor costs of food.
  The amount of time spent on the family's food.
  Using labor efficiently in relation to the family's food.
Money costs of food.
  The relative importance of food in the family's budget.
  Using money efficiently in obtaining the family's food.
  Using the foods themselves efficiently.
Planning for economy of labor and money in the day's meals.

Appraisal of food from the standpoint of economy involves analysis of the costs in labor and money. In most families, work connected with food takes more of the homemaker's time than any other activity. Likewise the money spent for food averages a larger proportion of the total expenditures for family living than any other item. Thus those who wish more time for other activities for the homemaker or more money for other purposes in the budget naturally look to both labor and money costs of food to see whether these might be reduced.

Employed single persons who prepare their own meals and the multitude of homemakers who now work outside the home are especially interested in time- and labor-saving practices in relation to food. When the alternatives are spending more time and effort versus spending more money, they may wisely choose to spend the extra money.

LABOR COSTS OF FOOD

The Amount of Time Spent on the Family's Food

A number of studies of the daily activities of rural homemakers agree very closely that the average time expenditure on food for the family is 3½ to 3¾ hours per day, more than one-third of the total working time. In larger towns and cities this is less on the average, so that, whereas the typical farm homemaker spends about

42 per cent of her working hours in preparing meals and washing dishes, the city homemaker spends about 31 per cent of her working day on these activities.[1]

Household labor costs for food include:

1. Labor of getting the food—raising it or purchasing it.
2. Labor of storing and processing—including preparation for eating.
3. Labor of serving and clearing up after meals.

The value to be assigned to household labor for any purpose depends upon the money or similar return which it might receive if devoted to other activities. When there is a surplus of family labor which has little or no opportunity to make other contributions to family welfare, either in the form of paid or unpaid work, a very small return may justify household production as compared with purchase in either a raw material or ready-to-eat form. Also, studies of nutritional welfare show that those families which produce the larger proportions of their own food tend to be better fed. This results from the competition of other items for the money budget and from the reluctance, of farm families especially, to pay retail prices for food which they are accustomed to selling at wholesale or less.

The evaluation of labor costs may be a matter not only of time but also of energy or skill or all three factors. Raising a garden requires strenuous effort on the part of someone. Homebaked bread can be more palatable than the commercial product, but it requires skill to produce it.

Using Labor Efficiently in Relation to the Family's Food

Efficient Practices in Getting Food

When the raw food is produced by family labor, efficiency is, of course, increased by recommended production practices, but the problem of deciding what foods to spend the labor on is also important. Thus, in raising a garden, effort put on such nutritious vegetables as spinach and other greens, cabbage, carrots, and tomatoes brings a much larger return in nutritive value than that devoted to cucumbers, sweet corn, or celery.

[1] See summary in Gross and Crandall, *Home Management*, F. S. Crofts and Co., New York (1947), p. 73.

Efficient Practices in Marketing for Food

These include:

1. *Planning several days' meals at one time.* This permits the consolidation of ordering and shopping and sometimes the preparation of raw materials in larger lots. An amazing proportion of families send someone to the store for food more than once a day. It should be possible to concentrate purchase of staples in one trip per week and more perishable foods in perhaps two trips.
2. *Shopping with a list.* This saves time at the store, makes unnecessary repeat trips to obtain items that were forgotten, ensures purchase of right amounts, and saves money by preventing "impulse" buying—the purchase of what appeals at the moment rather than what is needed or can be afforded.
3. *Shopping on the days and at the hours when business is the lightest.* This enables one to obtain more and speedier service at the store. Generally Friday and Saturday are the heaviest shopping days, and the busy hours are from ten to twelve in the morning and from three o'clock to closing time in the afternoon.

Efficient Practices in Meal Planning

These include:

1. *Planning several days' meals at one time.* In addition to saving shopping time, this saves actual planning time. At least three days makes an efficient planning unit and a week may be even better. Naturally one should allow for some flexibility, especially in seasonal items, to adjust to market supplies and prices.
2. *Using simplified menus.* Cutting down the number of foods to be served at a meal is an important time- and work-saving device. Palatable, nutritious meals can be built around one or two main dishes. The most efficient homemaker will not encourage a pattern of catering to individual preferences. She will plan menus suitable for family members of all ages. Foods appropriate for children are good for adults, and simple adjustments in the size of servings should be all that is usually necessary. Variety in sweet, rich desserts desired by adults may occasionally be provided and simple fresh or canned fruits substituted for children.

Modern families without extra help in the kitchen find that simplicity in menus need not detract from the pleasure of entertaining. Developing a specialty can stimulate as much eating enjoyment on such occasions as the sumptuous variety of traditional company meals. In fact, it is an exhibition of poor taste for the average

homemaker to serve elaborate guest meals. Guests should not be subjected to a hospitality marred by the consciousness that their hostess has labored excessively for their entertainment. Concentrating on the preparation of a few, well-selected dishes that are simply prepared but meet high standards of palatability, and serving them in an atmosphere of enjoyment rather than one of strain and weariness, win more appreciation than a banquet of many courses served by an exhausted hostess.

Besides, serving a large variety of foods tends to stimulate overeating. Many adults today, as a result of their sedentary work, must consciously restrict satisfaction of their appetites for food in the interest of their waistlines. The new-fashioned hostess does not think that setting the stage for gluttony is necessary to demonstrate hospitality.

Efficient Practices in Preparing Food

These include:

1. *Using simplified methods of preparation.* One of the trends in modern recipe making is simplification of steps in preparation. Often it is in the interest of efficiency to discard heirlooms in this field. Changes in manufacturing of shortenings, for example, make it possible to prepare acceptable cakes by the "one-bowl" method instead of by the more laborious creaming method. By simply adding a little more liquid, biscuits can be dropped instead of rolled. If rolled, they taste the same when square-cut to fit the shape of the dough as when a round biscuit cutter is used which leaves pieces to be reshaped.

2. *Using correct tools and utensils.* Efficient food preparation does not require expensive equipment. The BHNHE has prepared a recommended list for food preparation equipment based on a survey of homemakers' experience.[2]

3. *Using efficient kitchen arrangement.* Facilities for food preparation include working space, refrigerator, sink, and stove, which should be within easy reach of each other.[*]

4. *Using efficient working procedures.* These involve assembling utensils and ingredients before starting food preparation, using equipment correctly, and using motion-saving working procedures. Many common foods can be prepared in much less time if a little thought is

[2] "Tools for food preparation and dishwashing," *U. S. Dept. Agr., Home and Garden Bulletin* 3 (1951).

[*] State Agricultural Extension Services will furnish bulletins on kitchen planning upon requests of residents of the state.

given to redirection of motions. In one study it was found that the time for washing spinach was more than three times as long for some homemakers as for others.[3] Cutting leaves before washing, washing in warm water, using two pans of water, and using both hands to transfer the leaves from one pan to the other saved time.

5. *Preparing quantities for more than one meal at a time.* This labor-saving practice should not be employed when palatability deteriorates, sanitary quality becomes doubtful, or vitamin C in vegetables is sufficient to warrant conservation. When a freezer is available, many cooked foods can be satisfactorily conserved, and preparation in large quantities may then be desirable. Mixing dry ingredients in quantity for pie crust and other flour mixtures also saves labor.

6. *Buying ready-to-eat or partially prepared foods.* The trend of the market is toward offering more and more foods in at least a partially prepared form, such as washed greens, various flour mixes, "brown and serve" rolls, etc. In general, there is no question about their saving labor. This may often offset increases in money costs or other disadvantages.

Efficient Practices in Serving Meals

These include:

1. Having space near the stove for dishing up cooked foods.

2. Having the dining area in or near the kitchen.

3. Usually serving food at the table if dishes are saved by putting meat and vegetables on a single large platter. In some situations, labor is saved by serving plates in the kitchen if acceptable sizes of servings for each individual are known.

4. Using a tea wagon or tray to convey food to the table, and when possible to hold food for later courses.

5. Preparing food at the table—mixing salads, grilling, toasting, etc.

Efficient Practices in Clearing Up After Meals

These include:

1. Using a tea wagon or tray to convey leftover food and dishes to the kitchen.

2. Scraping and rinsing dishes immediately but consolidating dishwashing for more than one meal if facilities permit. It is usually more efficient to wash dishes and pans used in preparing food beforehand.

3. In washing dishes, rinsing and allowing them to drain dry rather than wiping them. This is also more sanitary.

[3] Gross and Everett, *J. Home Econ.*, 37: 159 (1945).

Efficiency in the use of labor connected with all aspects of food in family living includes sharing responsibilities among all members. This should not mean assigning only the less interesting tasks to others. Children and the masculine members may become expert in planning or buying and in preparing specialities, and may derive considerable satisfaction from these tasks.

MONEY COSTS OF FOOD

The Relative Importance of Food in the Family's Budget

As stated previously, food averages the largest single item among family expenditures. Whereas average city homemakers spent 31 per cent of their working time on activities connected with food, the BHNHE in a sample study of 1600 households in 68 cities in 1948 found average expenditures for food were 32 per cent of incomes. This is 6 per cent higher than the proportion spent by similar families in 1942. Foods went up in price relatively more than other items in family living, and families averaged better fare on their higher incomes.

Farm families average about the same proportion for food in their expenditures as do city families. Although they spend a smaller sum for food because they produce more at home, their total expenditures for all family living, especially housing, are also less.

A large percentage of families is not satisfied with its expenditures for food. Some would like to spend more, either because they suffer from hollow hunger or understand the perils of hidden hungers, or because they desire the gustatory pleasures of particular foods they cannot afford. Other families have pressing wants to which they would like to divert part of the money which now goes to food. Still others are not particularly concerned about the amount of money that they are spending for food but would like to be sure that their spending is efficient.

We have evidence that much food buying is not efficient, especially as this is measured by the nutritive value of the foods purchased. Surveys made by the BHNHE show that low expenditures for food tend to be associated with nutrient deficiencies more often than high, but some families fail to meet the recommended allowances for at least one nutrient at all spending levels.

Using Money Efficiently in Obtaining the Family's Food

Efficient spending for food is spending which brings relatively high satisfactions (health, enjoyment in eating, etc.) for the amount of money spent. Such spending requires thoughtful consideration of the following questions:

1. How much shall we spend for food?
2. What foods shall we buy?
3. How much of each food shall we buy?
4. What quality of each food shall we buy?
5. Where shall we buy each food?

Factors Affecting the Amount Actually Spent for Food

The actual amount spent for food by any particular family depends upon a number of factors, some of which will be briefly discussed in the following pages.

The Size of the Family. In general, the larger the family, the more is spent for food. However, the amount per person is usually less because small families average more adults who are more expensive to feed than small children; food can be purchased more economically and used more efficiently in larger families, and incomes do not tend to increase with size of family—larger families have, on the average, lower incomes than small families.

Individual Needs for Food and How They Are Met. Pregnant and lactating women, adolescents, physically active men, and sometimes persons on special therapeutic diets cost more to feed than others.

The Amount of Home Production of Food. As mentioned previously, farm families on the average raise about half of their food. Nutrition would be improved for many, and money released for other items, if this were increased to three-fourths. A surprisingly large proportion, almost half, of city families do some home canning according to a BHNHE survey, presumably at least in part because it saves money.

The Size of the Family Income. The distribution of family incomes in the United States for the period 1948 through 1951 is given in Table VIII. In October, 1950, the Bureau of Labor Statistics found that the total annual cost of a "modest but adequate" worker's family budget ranged from \$3453 to \$3933 in 34 large cities in the United States. The estimate assumed a family of 4 persons including 2 children under 15 years of age. Since the median

Table VIII. Income grouping of family units and of total money income before taxes * (percentage distribution)

[From *The Federal Reserve Bulletin*, September (1952)]

Money income before taxes	1951		1950		1949		1948	
	Family units †	Total money income	Family units †	Total money income	Family units †	Total money income	Family units †	Total money income
Under $1000	11	1	11	1	13	2	11	2
$1000–$1999	13	4	15	6	15	6	15	6
$2000–$2999	16	9	16	10	18	12	20	12
$3000–$3999	17	14	18	16	19	18	20	18
$4000–$4999	15	16	13	14	12	14	12	14
$5000–$7499	17	24	18	26	15	23	14	21
$7500–$9999	6	32	5	27	4	25	4	27
$10,000 and over	5		4		4		4	
All cases	100	100	100	100	100	100	100	100
Median income	$3530		$3400		$3100		$3120	
Mean income	$4320		$3990		$3750		$4020	
Number of cases	2501		3029		3069		3068	

* Income data for each year are based on interviews during January, February, and early March of the following year. Family units are defined as all persons living in the same dwelling who are related by blood, marriage, or adoption.

† Includes single-person family units.

Table IX. Size of families within income groups (percentage distribution of family units)

[From *The Federal Reserve Bulletin*, September (1952)]

Number of persons in family unit	Annual money income before taxes															
	All income groups		Under $1000		$1000–$1999		$2000–$2999		$3000–$3999		$4000–$4999		$5000–$7499		$7500 and over	
	1951	1950	1951	1950	1951	1950	1951	1950	1951	1950	1951	1950	1951	1950	1951	1950
One	12	12	41	45	21	19	14	13	9	7	3	4	2	2	3	1
Two	29	29	35	28	34	38	33	33	26	26	28	27	25	27	24	21
Three	21	21	8	11	19	18	18	18	23	24	27	25	26	26	23	22
Four	19	19	5	7	8	11	17	17	22	24	25	19	23	23	28	27
Five or more	19	19	11	8	18	14	18	19	19	19	17	25	24	22	22	29
Not ascertained	*	*	*	1	*	*	*	*	1	*	*	*	*	*	*	*
All cases	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Number of cases	2501	3029	202	334	269	397	352	420	395	495	383	400	505	595	395	388

* No cases reported or less than one-half of 1 per cent.

(middle) family income was found to be only $3400, it is likely that some families did not have enough money to buy adequate food, and many others would have had to use skill and care in buying if they were to achieve nutritional adequacy. This is emphasized by the fact that 19 per cent of families receiving $2000 to $2999 included 5 or more members, although part of these no doubt lived on farms where lower incomes would not affect the quality of nutrition to the same degree as living in a city. See Table IX.

The Season of the Year. In general, food costs tend to be lower in the summer and fall than in the winter and spring.

The Location. Food prices vary with the section of the country and with the location of the food market—in a small town or city. In general, the southern part of the country has lower food prices than the northern, and small towns and cities have lower prices than large cities.

Table X. Consumer price indices for foods and "all items"

(1947–1949 = 100)

Year		All items	Food
1913	Average	42.3	39.6
1914	July (Prewar)	42.9	40.4
1918	December (War's end)	70.6	74.1
1920	June (Postwar high)	89.4	91.6
1922	August (Postwar low)	70.9	58.4
1929	Average	73.3	65.6
1933	April (Depression low)	53.6	37.7
1939	Average	59.4	47.1
	August (Prewar)	59.0	46.3
1940	Average	59.9	47.8
1941	Average	62.9	52.2
	December (War's beginning)	66.1	56.0
1942	Average	69.7	61.3
1943	Average (Price control)	74.0	68.3
1944	Average	75.2	67.4
1945	Average	76.9	68.9
	August (War's end)	77.5	69.8
1946	Average	83.4	79.0
	June (End price control)	79.8	72.1
	December	91.9	92.0
1947	Average	95.5	95.9
1948	Average	102.8	104.1
1949	Average	101.8	100.0
1950	Average	102.8	101.2
1951	Average	111.0	112.6
1952	Average	113.5	114.6

The General Price Level for Food. Food prices change from year to year as well as from season to season. The Bureau of Labor Statistics collects monthly prices on a standard market basket of foods based on purchases by moderate income families in 34 selected cities. These are reported as an index number with the years 1947–1949 as a base period represented by 100. Index numbers for selected years after 1913 are given in Table X. The August, 1952, price level for food was the highest in our history up to that time—index number 116.6.

The Proportion of Meals in Commercial Eating Places. Meals "eaten out" generally cost at least twice that of similar food prepared at home.

Family Customs and Preferences. This includes the extent to which entertaining is centered around food. These factors are, of course, extremely variable and in some families add substantially to food expenditures.

Deciding How Much To Spend for Food

The average cost of one week's food at December, 1950, prices for families and individuals for both the low- and moderate-cost master food plans given in Chapter 1 are estimated in Table XI.*

The proportions of incomes each level would take is estimated in Table XII. This gives some basis for judging whether a family's spending for food is out of line with its resources or not.

If the existing level of expenditure is not sufficient to buy the foods specified in the Low-Cost Master Plan, either the amount spent for food should be increased or some other means found to make certain that nutritional needs of the family are met. It is possible to devise a nutritionally safe plan at lower cost, but the Bureau states that its Low-Cost Plan already assumes less than average waste and better than average skill in applying nutritional principles to food management.

The least costly methods of improving nutrition when expenditures are inadequate and money resources limited are to increase home production by raising more food, to omit all ready-to-eat or partially prepared foods from the market order, and to eat all meals

* The index number for food in December, 1950, was 107.1. The estimated costs in Table XI may be revised to adjust to changes in the general price level for food by using the current number for this item which is published regularly in *The Monthly Labor Review*.

Table XI. Estimated cost of 1 week's food, BHNHE Food Plans,* December, 1950

(Index for food, 107.1)

Age and activity groups	Low-cost adequate diet, dollars	Moderate-cost adequate diet, dollars
Families		
Family of two †	10.85–11.80	15.70–16.45
Family of four with preschool children ‡	14.90–16.20	21.45–22.45
Family of four, school age children §	17.30–18.90	24.80–26.00
Individuals		
Children		
9–12 months	2.25– 2.35	2.60– 2.65
1–3 years	2.50– 2.70	3.50– 3.60
4–6 years	3.10– 3.30	4.30– 4.45
7–9 years	3.70– 4.00	5.10– 5.30
10–12 years	4.30– 4.70	6.00– 6.30
Girls		
13–15 years	4.60– 5.00	6.65– 6.95
16–20 years	4.25– 4.65	6.30– 6.60
Boys		
13–15 years	5.00– 5.50	7.35– 7.75
16–20 years	5.40– 6.05	8.20– 8.60
Women		
Sedentary	4.15– 4.50	5.85– 6.10
Moderately active	4.45– 4.85	6.45– 6.75
Very active	4.85– 5.35	7.25– 7.65
Pregnant	5.15– 5.55	7.05– 7.35
Nursing	6.20– 6.65	8.00– 8.35
60 years or over	4.10– 4.45	5.85– 6.15
Men		
Sedentary	4.45– 4.85	6.45– 6.75
Physically active	4.85– 5.35	7.25– 7.65
Very active	5.80– 6.60	9.05– 9.60
60 years or over	4.35– 4.75	6.40– 6.65

* These estimates were computed from quantities in low- and moderate-cost food plans, "Helping Families Plan Food Budgets," *U. S. Dept. Agr., Misc. Publ.* 662, with prices from "Average retail prices of food in 56 large cities combined," released periodically by the Bureau of Labor Statistics.

† Physically active man and sedentary woman. 20 per cent added for adjustment for family size.

‡ Physically active man and moderately active woman; children, 1–3 and 4–6 years.

§ Physically active man and moderately active woman; children, 7–9 and 10–12 years.

Note: All costs have been rounded to nearest $0.05.

Table XII. Per cent of income that would be required to purchase quantities of food in low- and moderate-cost plans, families of 2 and 4 persons at different income levels, December, 1950

(Index for food, 107.1)

Weekly family income, dollars	Family of 2 persons *		Family of 4 persons †	
	Low-cost plan, %	Moderate-cost plan, %	Low-cost plan, %	Moderate-cost plan, %
100	10–12	15–16	17–19	24–26
80	13–15	19–21	22–24	31–33
60	17–20	25–27	29–31	41–44
40	26–30	39–41	43–47	Over 50
20	Over 50	Over 50	Over 50	Over 50

* Active man and sedentary woman.

† Active man, moderately active woman, and 2 children of school age.

at home. If these measures are not sufficient, public assistance, including school lunches for the children, should be sought.

Families that would like to divert a part of the money now being spent for food to other uses may also use the Low-Cost Master Plan as a guide. If their present expenditures are larger than those required for this plan, they may safely reduce them if they follow the recommended pattern of choices.

Other families whose financial situation permits expenditures at a higher level than that required for the Low-Cost Plan may indulge preferences for a greater variety and more expensive foods, and still maintain nutritional adequacy by following the Moderate-Cost Plan. Farm families can usually adopt this plan without increasing their cash expenditures for food.

Deciding What Foods to Buy

We have defined efficient food choices as those which bring relatively high satisfactions, especially health, in relation to their cost. With this as the foremost criterion, one who has broad knowledge of food equivalents can at the same time consider family and individual preferences over a wide range of costs. Every category in the Master Food Plans offers some choice among equivalents. No food except milk (or certain of its products) is indispensable. One can adjust preferences to relative costs by choosing

tomatoes *or* citrus fruits *or* raw cabbage in one group, and spinach *or* other greens *or* carrots in another. Later chapters in this book include discussion of relative nutritive values and costs of all these groups of foods.

The form in which a particular food is marketed may greatly affect the cost when there is little or no difference in nutritive quality. For example, frozen vegetables may cost more than three times as much as canned.

Best buys which are generally available in the eleven categories of the Master Food Plans are as follows:

1. Leafy green and yellow vegetables—spinach, canned or fresh, carrots, squash.
2. Citrus fruit, tomatoes—canned or frozen grapefruit juice, canned or frozen orange juice.
3. Potatoes, sweet potatoes—fresh, kind depending upon location.
4. Other vegetables and fruits—nutritive differences not important. Choose whichever is cheapest per serving. Dried fruits usually most economical.
5. Milk—fresh or dried skim, cottage cheese for protein but not for calcium, evaporated milk, cheapest American cheese.
6. Meat, poultry, fish—liver, kidneys, heart. Other cuts of meat and fish, whatever is cheapest per pound of edible portion.
7. Eggs—whatever size is priced to give the largest weight per unit cost, usually the extremes in size.
8. Dry beans, peas and nuts—unprocessed dry beans and peas, peanut butter.
9. Flour, cereals—pastry flour if enriched and not to be used for bread making; the enriched all-purpose or family flour for bread making at home which has the lowest price per pound; uncooked, whole-grain or fortified breakfast foods which have the lowest price per pound; enriched corn meal.
10. Fats and oils—fortified margarine, plain lard.
11. Sugar, sirups, preserves—granulated sugar, molasses.

At the University of Nebraska, a group of 8 college women compared their experiences when eating meals planned on a BHNHE Low-Cost Plan with those of two free choice control groups whose food cost about 20 per cent more. Meals were about equally nutritious in all the groups except that the free choice groups had less than the recommended amount of protein. Much more time, effort, and ingenuity were spent in planning, marketing, and preparing food to make the low-cost meals appetizing. The greatest

savings in food costs came from the use of (1) unprepared cereals rather than prepared ones, (2) potatoes in generous quantities, (3) inexpensive table and cooking fats and (4) much less of such prepared items as desserts, salad dressings, condiments, and relishes.[4]

In planning low-cost meals it is particularly important to include a good source of vitamin C because the staple low-cost foods are deficient in this nutrient. Also the richest sources of vitamin C are likely to be omitted because they do not furnish much else and seem extravagant to the nutritionally uninformed. Vitamin A likewise needs guarding if liver is not included.[5]

As the amount of money assigned to the food budget rises, body needs can be met by choices which include more variety and larger amounts of preferred foods. The variety of exotic and out-of-season foods now offered by the food markets, even in relatively isolated sections, greatly increases the range of possible choices. The promotion of new foods and the development of new forms of commercial processing are also constantly adding to the variety available. The development of new varieties, of tomatoes for example, extends the area of successful production so that the same trend applies to both the home garden and to the local market.

Identifying Foods at the Market. On first thought, this discussion might be considered superfluous. But, although one is certain to be able to recognize an egg or a potato when one sees it, there remain problems of identifying unfamiliar foods and of being certain of what one is getting in processed foods, whether sold under common names or synthetic names, or whether open to inspection at the store or sold in opaque packages. Even in the case of such a simple food as butter, Congress found it advisable to establish a definition by passing a special law many years ago. Otherwise there would have been no generally accepted answer to the question, "How much milk fat does it take to make a product qualify as butter?"

Legal Aids to Consumers in Identifying Foods. The federal food law divides foods into three classes from the standpoint of establishing their identity: (1) standardized foods, (2) unstandardized foods, and (3) special foods.

Standardized foods. When, in the judgment of the administrator, it will promote honesty and fair dealing in the interest of

[4] Leverton and McMillan, *J. Home Econ.*, 36: 225 (1944).

[5] Rollins, *J. Home Econ.*, 40: 311 (1948).

consumers, he is authorized to promulgate regulations fixing a reasonable definition and standard of identity of a food. So far as possible, this must be under its common or usual name. This provision is intended to be applied only to staple foods, and not all of them have been covered as yet. Among the foods now defined are common canned fruits and vegetables, jellies, preserves, jams, fruit butters, catsup, juices, common cheeses, types of cream, milk, shellfish, egg products, and flours.

Definitions of standardized foods are very specific, for example, "evaporated milk is the liquid food made by evaporating sweet milk to such point that it contains not less than 7.9 per cent of milk fat and not less than 25.9 per cent of total milk solids." Optional ingredients are a limited amount of disodium phosphate, sodium citrate, or both, or calcium chloride and vitamin D to make the total potency not less than 7.5 USP units per ounce. When such a standard has been established, any product bearing the name must conform or be declared "misbranded" and subject to condemnation. Other ingredients may not be added even if nutritionally valuable. In such cases a different name must be used for the product and indicated on the label.

Unstandardized foods. A food for which no definition or standard of identity has been promulgated must be labeled informatively with either the common or usual name, if it has one, or, when it is made from two or more ingredients, with the common or usual name of each ingredient. Exact quantities of ingredients need not be disclosed nor the exact identity of flavors, spices, or coloring.

Unlabeled foods, that is foods sold in bulk, are exempt from listing of ingredients. Likewise, a number of staple foods, ice cream for example, are exempted by administrative action, presumably temporarily until a definition and standard of identity are decided upon. In the case of these latter foods, however, unusual ingredients are supposed to be indicated.

Special foods. Food products which come within the class of those having special dietary uses include any that claim to (*a*) supply particular dietary needs as a result of such conditions as disease, convalescence, pregnancy, lactation, allergy, underweight, or overweight, (*b*) supply particular dietary needs at different ages—usually infancy and childhood, and (*c*) fortify the ordinary diet with one or more nutrients. When a food purports to have a special dietary use, its label must bear such information about its dietary properties as the administrator considers necessary to inform

purchasers fully with respect to its value for the purpose. This provision helps consumers to get their money's worth since these products are often costly. It also aids them by requiring that information be given to support any special claims in regard to health or medical values. Like all other information on food labels, this must be truthful or the product may be declared misbranded and its sale forbidden in interstate commerce.

Some "special" foods fortified with particular nutrients are also standardized. Thus "enriched bread" is defined to contain definite amounts of thiamine, riboflavin, niacin, and iron. In general, the administrator of the federal law restricts the use of the term "enriched" to foods which have been standardized, the definition specifying the kind and amount of nutrients to be added. When unstandardized foods become "special" foods as a result of addition of nutrients, they may be designated as fortified with the particular ingredient added, "ascorbic acid added," for example, appearing on the label of an orange drink.

When information about potency is given, it is often stated in terms of the *Minimum Daily Requirement.* This does not refer to the *Recommended Allowances* but to a set of standards accepted by the Food and Drug Administration for use in labeling foods. These are given in Table XIII. Whereas the *Recommended Allowance* of ascorbic acid for an adult man is 75 mg., the *Minimum Daily Requirement* is 30 mg.

Table XIII. Minimum daily requirements for food labeling purposes

[Federal Food, Drug and Cosmetic Act, *Federal Register*, November 22, 1941]

Nutrient	Infant	Child, 1–6 years	Child, 6–12 years	Adult
Calcium, mg.	Not established	750.0	750.0	750.0
Phosphorus, mg.	Not established	750.0	750.0	750.0
Iron, mg.	Not established	7.5	10.0	10.0
Vitamin A, USP units	1500.0	3000.0	3000.0	4000.0
Vitamin B, mg.	0.25	0.50	0.75	1.0
Vitamin C, mg.	10.0	20.0	20.0	30.0
Riboflavin, mg.	0.5	Not established	Not established	2.0
Vitamin D, USP units	400.0	400.0	400.0	400.0

The problem of selecting foods according to their nutritive value is complicated by natural variations in potency, especially of vitamins, as well as by variations produced by fortification. Our laws do not require food labels to bear information on this point except when they carry a claim of special dietary use. In fact, the federal

law defines food as *any article used for food or drink by man or animal.* This is interpreted to include substances added to food which may have no nutritive value whatever, for example, artificial colorings, condiments, flavors, spices, and preservatives. Perhaps, in the future, as consumers become better educated about nutritive values, more information about them will be voluntarily placed on labels. In the meantime, the safest procedure is (*a*) to plan for sufficiently generous consumption of foods carrying those nutrients which are especially likely to be deficient to compensate for natural variations, and (*b*) to discount the significance of indicated fortifications unless they are standardized by law or given in specific quantities.

As is always the case, the federal law does not cover foods produced and sold within a state. Thus legal aids to help consumers to identify such foods depends upon laws within the particular state.

OTHER AIDS TO CONSUMERS IN THE IDENTIFICATION OF FOODS. Additional sources of information about the identity of foods are *voluntary statements on labels, advertising, and the salesclerk.*

Voluntary statements on labels may be a source of information about the identity of foods. The federal food law makes it illegal for labels to bear any false or misleading statement. This provision is broadly defined to cover sizes of type, other factors affecting readability such as contrast between type and background, and the pictorial matter as well as the actual wording. Misleading brand names such as "Nulade Eggs" applied to cold storage eggs are forbidden. Titles cannot give prominence to the name of a valuable ingredient present in only insignificant amounts; for example, a cane sirup containing only enough maple sirup to contribute maple flavor must be called "cane sirup flavored with maple" rather than "cane and maple sirup." In general, such information as the producer or manufacturer chooses to give on the label about the nature of the food is a reliable guide to consumers.

Advertising as a source of information about the identity of foods. The truthfulness of advertising, like that of statements on labels, is now subject to federal jurisdiction when the advertising is disseminated by United States mails, in interstate commerce by any means, or by any other means likely to or intended to induce a purchase in interstate commerce. The Federal Trade Commission is entrusted with enforcement of the law. In determining whether any advertisement is misleading, it is directed to take into account "not only representations made or suggested by statement, word, design,

device, sound, or any combination thereof, but also the extent to which the advertisement fails to reveal facts material in the light of such representations."

The Federal Trade Commission now scrutinizes the advertising found in newspapers, magazines, catalogues, and almanacs, and given over the radio. It does not dictate what an advertiser must say, but rather what he must *not* say to prevent false and misleading claims. The Commission's convictions include only a small proportion of cases involving food advertising. From the consumer's point of view, most food advertising is to be condemned not for the misinformation it carries, but for its vague, insignificant, and irrelevant statements, especially about quality, which will be discussed later. So far as helping food buyers to establish identity of a food, the most valuable service of advertising has been to help call new foods to their attention and to give information about their composition and use. This role of advertising might well be improved by making the material more informative than it is.

The salesclerk as a source of information about the identity of foods. Depending upon the salesclerk for any type of information about the foods he sells has the following marked limitations:

(*a*) Under modern mass-marketing conditions, the role of the salesclerk has been restricted to the packaging of relatively few products sold in bulk and to the collecting of the money. It is either inconvenient or impossible to try to obtain detailed information from him.

(*b*) The chances are that he will not possess reliable information about the points in question. This is not always the case, however, and this statement does not imply that the buyer may not be able to obtain useful information if the opportunity to ask is available. But an average grocery store stock includes a thousand items or more. It is unreasonable to expect a clerk to have the significant facts about each one of them.

(*c*) The salesclerk has a natural bias in favor of his own financial advantage. Although to a certain extent his long-time interest is satisfaction of his customers, it is too much to expect that this will be his primary consideration in answering a specific question. His margins on different products vary, and his advice will naturally be influenced by this fact. After all, few consumers are sufficiently discriminating to discover such discrepancies and he knows it.

Deciding What Quantity of Food to Buy

Efficiency in buying food requires the making of wise decisions about the amount of each food to purchase. It also requires the ability to recognize specified quantities and to use quantity as the basis of price comparisons. Factors to be considered in deciding on the size of units to purchase include: *

Purchase price per unit measure in quantities of different size. Does it cost less per unit measure to buy the larger quantity?

Probable rate of consumption. Will purchase in large units compel monotonous repetition in menus? Will the mere presence of a larger quantity or the fear of storage losses stimulate overconsumption or wasteful use of the food?

Household storage facilities. Is there adequate storage space? Are the environmental conditions suited to preventing deterioration during the period of holding?

Significance of the money invested. Do money resources make it possible or convenient to invest in food supplies for future use?

In general, buying in larger quantities results in a saving in first cost, diminishes the time required for marketing, and affords the convenience of having supplies at hand when marketing is interfered with. Losses from spoilage during storage, or lavish use, may more than offset these advantages, however. But the limitation of mere space for storage and the lack of funds to invest in more than hand-to-mouth supplies force many families to buy in inefficient quantities.

Securing and Recognizing the Quantities Desired. One who wishes to buy efficiently must know how to recognize quantity at the market for the purpose of making price comparisons and determining whether the specified quantity has been obtained.

Certain legal measures help food buyers to recognize quantity, but intelligent judging requires vigilance to see that laws are enforced and to supplement them in respects that will be discussed later.

LEGAL AIDS TO CONSUMERS IN IDENTIFYING QUANTITY OF FOODS BOUGHT. Consumers are helped in this phase of food buying by laws which:

* In periods when war or other economic emergencies result in short market supplies, the socially responsible citizen will consider the effect of the size of his purchases upon the supply available to others. Such individuals will also scrupulously resist the impulse to hoard.

1. Require accuracy of weighing and measuring devices.
2. Require a statement of quantity in terms of weight, measure, or count to appear on labels of packaged foods.
3. Prevent deceptive packaging by forbidding the use of containers "so made, formed or filled" as to be misleading.
4. Standardize certain containers by limiting the number of sizes.

Accuracy of weighing and measuring devices. State laws and city ordinances provide for accuracy of weighing and measuring devices by requiring inspection. Inspected scales bear a seal with which it is illegal to tamper.

Statements of quantity on labels. The requirement that quantity be stated on labels of packaged foods is part of the federal food law enforced by the Food and Drug Administration, but is supplemented by state laws covering products in intrastate trade. The quantity stated refers to the amount of food exclusive of wrapping or container materials, but it includes any brine, sauce, sirup, oil, or other packing medium if it is edible and usually consumed by the purchaser. In the case of olives or pickles packed in wine or vinegar which is not usually consumed, the quantity stated may be in terms of weight of drained product, liquid measure of drained product, or numerical count.

The unit measure to be used is limited by the nature of the food. Foods in liquid form must be declared in terms of liquid measure—quarts, pints, or fluid ounces. For solids and semisolids, including viscous foods or mixtures of solids and liquids, weight—pounds or ounces—must be used, except that dry measure (based on the bushel) may be used for fresh fruits, vegetables, grains, etc. A quart liquid measure is based on the U. S. gallon (231 cubic inches) and contains 57.75 cubic inches. A dry quart is based on the bushel and contains 67.21 cubic inches. Many of the foods sold by dry measure have legal weights per bushel established by the individual states. In enforcing the federal law, it has been ruled that the largest possible unit must be employed on the label, for example, "one fluid quart," not "2 pints" or "32 fluid ounces." Small packages, less than one-half ounce either weight or fluid, are exempt from the federal quantity-labeling requirement.

Deceptive packaging. Deceptive packaging, forbidden by the federal food law, includes the use of containers made in a form which may be misleading, for example, bottles with thick sides and bottoms, or packages with yellow cellophane windows for noodles, giving the impression they are made with eggs, the use of

containers shaped in a deceptive manner, for example, boxes with indented bottoms, or bottles with long necks, and "slack-filling" of containers. It is also required that any outer cartons fit the container inside.

"Slack-filling" is not to be confused with short-weighting. The statement of contents on the label may be correct but the package may be "slack-filled." The contents must reasonably fill the container. In addition, the amount of solids in canned foods packed in added liquids must be as much as it is practical to get into the can. A head space of about one-tenth the can height is allowed, and the proportion of solids is variously defined for different products, but in general is expected to be as much as can be put in the can without crushing the pieces before processing.

Standardization of containers. Federal laws standardize the following types of containers by limiting the number of sizes of each and specifying the quantity in cubic inches each must hold: barrels, berry boxes, till boxes, Climax baskets (used for grapes), splint (market) baskets, round stave baskets, and hampers. The barrel standard applies to containers used in both inter- and intrastate trade, and is enforced by the National Bureau of Standards. The standards for other containers apply only to interstate commerce and are enforced by the U. S. Department of Agriculture, but most of the states have established similar standards, especially for berry boxes, till baskets, and Climax baskets.

PRECAUTIONS BUYERS SHOULD TAKE TO IDENTIFY QUANTITY IN FOOD PURCHASES. The legal protections discussed do not by themselves ensure that a food buyer will get the amount expected. Desirable shopping practices include: (1) specifying the appropriate unit in making the purchase, (2) reading labels and resisting judging quantity by eye, and (3) checking to see that weights and measures are honestly used.

Specifying the appropriate quantity unit. Weight usually gives more uniform amounts than count, and, except for liquids or finely divided materials, it is a better purchase unit than volume for bulk products. Large fruits such as peaches or apples should not be sold by measure in small containers because these are deceiving in appearance. Weights per bushel of fruits, vegetables, and grains differ from state to state; hence a food buyer should learn the legal standards for the state in which the purchase is made. Asking for a "quarter's worth" or enough for four servings is an inefficient

buying practice. It leaves the decision about quantity to the discretion of the salesman and invites undermeasure.

Reading labels. It is seldom safe to judge amounts by the eye, that is, by apparent size of package, in spite of the legal protection against "slack-fill" and against the use of containers formed or shaped so as to mislead the consumer. By changing the shape of a loaf of bread in an entirely legal fashion, a baker can easily conceal a two-ounce reduction in size. Reading the label is the safest way to judge quantity, as stated previously.

Even when one reads labels, price comparisons may still require excessively complicated calculations as a result of lack of standardization of packages. This problem applies to tin cans, glass containers, paper and wooden boxes, cartons, crates, sacks, and bags. In 1941 there were 258 sizes of tin cans on the grocers' shelves. There were several thousand sizes and shapes of glass containers. Entirely legal changes in shapes and sizes of packages can reduce cubical contents substantially without noticeably affecting apparent size. The increasing substitution of a can size known to the trade as No. 303 for the No. 2, long in common use for vegetables, has undoubtedly often been unnoticed by food shoppers. But the No. 303 holds 3 or 4 ounces, about one-fifth, less than the No. 2.

If consumers exerted group political pressure, all common types of packages might be standardized in shapes and limited in sizes to greatly facilitate shopping. As far back as 1940, the National Bureau of Standards recommended limiting the number of can sizes and shapes for all fruits and vegetables to 46.

Unstandardized units of such staple foods as bread also frequently deceive shoppers and make price comparisons difficult. The Bureau of Standards has recommended that bread be sold only in the following sizes of loaves: 1 pound, ½ pound, 1½ pounds, or multiples of 1 pound.

Checking to see that weights and measures are honestly used. Designations of quantity appearing on the labels of packages, especially those which have entered into interstate commerce, can generally be trusted. Exceptions are easily opened containers such as the open mesh bags often used for oranges or onions. Spoiled units are visible, and although they should be removed and replaced, the latter step is occasionally omitted. Other comparatively common dishonest practices are weighing the hand, heavy packing materials, or slugs with the food, removing the merchandise from the scale platform before the pointer comes to a rest, setting the rest point of

the pointer past zero, and substituting the smaller liquid quart measure for a dry quart measure in measuring nonliquids.

The shopper who orders by specific weight can usually prevent these practices by watching the weighing at the store. Checking store weights on an accurate kitchen scale gives one a basis for claiming redress if a shortage is revealed. A particular group of foods which should receive a household checking of weight is those foods which have been weighed into bags at the store from bulk supplies in the absence of the purchaser. "Five-pound" packages of sugar weighed to contain four ounces less than this amount do not reveal their shortage by appearance. Weight of chickens, fish, and other meats dressed or trimmed at the store must be checked at the store. When short weight is received, it is best to call it to the attention of the salesman, but, if one is reluctant to do this, and especially if there is reason to believe that it is a persistent practice, the purchaser should inform the state or local weights and measures official.

Deciding What Quality of Food to Buy

The meaning of the word *quality* as here used is restricted to differences in palatability and occasionally in nutritive value in relation to cost. Quality in this sense is affected by (1) deliberate substitutions and other deceptions practiced during manufacture or distribution and (2) natural differences related to variety, breed, weather, insect damage, or other conditions of production and, for processed foods, differences related to measures used in processing. Foods in which palatability qualities are closely related to nutritive value are relatively few and include primarily fresh fruits and vegetables. As will be discussed in the chapter on these foods, wilting and poor color, for example, may be associated with lowered content of certain vitamins. Of course, the type of defect or damage that results in preparation waste reduces food value received for one's money and is also a matter of nutritional economy.

Provisions of the federal food law prohibit the sale of foods that have had their quality lowered by two types of deliberate changes: (1) concealing damage or inferiority and (2) adding or packing in a substance which increases bulk or weight, or reduces quality or strength, or makes the product appear of greater value than it is. Thus noodles may not be sold when they have been artificially colored to give the impression that egg yolk is an ingredient, even when

the coloring is an approved one and declared on the label. Milk containing added water, or oysters which have been soaked in fresh water, which increases their size, cannot be sold legally.

For the most part, intelligent buying of foods requires concern with market quality for the purpose of getting one's money's worth. If one wants to pay for superior palatability qualities he should get them. But buying "the best" in food is not closely related to its healthfulness, and often skilled preparation can overcome shortcoming in the eating quality of the raw product. Canned tomatoes do not need to be unbroken, evenly ripened and free from defects to make excellent cream of tomato soup. Price differences between the "best" and the ordinary in food may be very great. Consumers should select quality to fit the use and their purses.

Identifying Quality at the Market. Identifying quality is the most difficult phase of intelligent shopping for food. This is in part a result of the complexity of the problem of arriving at simple, uniform designations of quality called *grades* and in part a result of the reluctance of producers and distributors to put such designations on labels. Producers and distributors of goods of low or medium quality are afraid that declaration of the fact will arouse unfavorable discrimination on the part of the consumer that will not be offset by the usual difference in price as compared with that of the product of high quality. Most producers and distributors who advertise believe that uniform quality designations will destroy brand prestige and thus work to their individual disadvantage. Limited aid to consumers in identifying quality of foods is provided, but much remains to be learned by study and experience.

LEGAL AIDS IN IDENTIFYING QUALITY IN FOODS. Four major types of legal protection help us to judge the quality of foods at the market: (1) laws which require appropriate labeling when there has been substitution or removal of valuable constituents in foods, (2) laws which establish a minimum standard of quality and require appropriate labeling when the food is substandard, (3) laws which require designation of grade, and (4) laws which require the declaration on the label of artificial flavorings or colorings and the fact that a food is an imitation of some other food.

Laws which require appropriate labeling when there has been substitution or removal of valuable constituents in foods. The federal food law contains provisions deeming a food to be adulterated "if any valuable constituent has been in whole or in part removed," or "if any substance has been substituted in whole or in part there-

for." Often foods of these types may be sold legally if the name is modified appropriately, but not always. Butter with less than 80 per cent milk fat is not legal, but dry milk solids made from skim milk can be sold if labeled "non-fat milk solids." Shredded coconut may be sold when sugar is added if the title on the label is "shredded coconut with sugar added." Grape juice may be sold when sweetened with dry sugar but not if it is diluted with a sugar sirup, unless the name is changed accordingly. In general, substitutions are permitted only when they do not lower the value of the product for the purposes for which it is intended and are not otherwise detrimental to it.

Laws which establish a minimum standard of quality and require appropriate labeling when the food is substandard. The federal food law authorizes the administrator to set a reasonable standard of quality for all foods except fresh and dried fruits and vegetables, and butter. All products falling below the standard are required to be labeled "substandard." So far, a "reasonable standard" has been established for relatively few foods, mostly canned fruits and vegetables. Of course, the "substandard" food must be wholesome, but it may be inferior in palatability and remain normal in food value, for example, peas which rate "substandard" because they are overmature.

Laws which require designation of grade. Grades are ratings of quality based on the more important palatability qualities entering into market value. They may be established by governmental or business agencies. The latter offer consumers little help because the ratings vary from brand to brand and may be changed at the discretion of the business management. Governmental grades may be compulsory or optional; those in effect have been established by:

(*a*) *The United States Department of Agriculture.* These grades are of three classes: the compulsory grades which must be used, permissive grades which are recommended but optional, and tentatives grades which are in a testing stage and optional. Compulsory grades apply to grains at all times, but have been extended temporarily to other foods, such as meat, during emergency periods when the government is controlling prices.

(*b*) *State governments.* State grades may be compulsory or optional within the particular state. They often cover eggs, for example.

(*c*) *Municipalities.* Cities may pass ordinances requiring the use of certain federal, state, or locally defined grades. The most common apply to milk.

Grading of food products according to governmental grade specifications is widely practiced to facilitate wholesale buying and selling, but compulsory grade labeling of foods as they appear in the retail store is limited to state and local grades which cover only a few foods, except during emergencies as mentioned previously, when compulsory federal grade labeling is applied to selected foods.

To facilitate use by consumers, grade designations should be relatively few in number, simple, uniform, and easy to place in the quality scale. The federal grades for canned fruits and vegetables, A, B, C, and "substandard" meet these requirements, but those in common use for many other foods do not. Examples of confusing grade designations include those for beef (Prime, Choice, Good, Commercial, Utility) and those for potatoes (U. S. Fancy, U. S. Extra No. 1, U. S. No. 1, U. S. Commercial, U. S. No. 2).

Most unbiased students of the methods by which consumers may identify quality at the market agree that government grades are the most useful. They offer these advantages: (*a*) They make it possible to save money by selecting the quality which fits the use. (*b*) They make inspection before buying unnecessary. (*c*) They make accurate price comparisons possible. (*d*) They tend to make price conform to quality. This permits the consumer who wishes to obtain maximum nutritive value for her money to do so by selecting the lower grades.

Laws which require the declaration on the label of artificial flavorings or colorings and the fact that a food is an imitation of some other food. Artificial flavorings include all synthetic substances which affect flavor but do not include natural food substances, such as concentrated fruit or fruit juices. They need not be specified by name but by some such appropriate term as "artificial flavoring" or "artificial seasoning." The only foods exempted from this requirement are a few such as cherries in canned fruit cocktails where the established definition includes artificial flavoring as an ingredient.

Artificial coloring includes any coloring matter, whether it is synthetic such as a certified aniline dye, natural such as saffron, or a mineral such as iron oxide used to color fish pastes. "Color added" or "artificial color added" are considered appropriate designations. Butter, cheese, and ice cream are exempted from this requirement.

In general, an imitation food is one which is patterned after a superior one. If it resembles closely the genuine article it must be labeled as an imitation of it whether the name refers to the counterpart or not. For example, products can be manufactured without containing any lime or lemon juice which cannot be differentiated from them without chemical tests. Even when sold under trade names which do not mention the fruit, they must be labeled imitations. The mere resemblance of one food to another, oleomargarine to butter, for instance, does not make it an imitation, however. In effect, it is the deceptive nature of a product which determines that it shall be considered an imitation.

OTHER AIDS TO CONSUMERS IN IDENTIFYING QUALITY. Additional sources of information about quality of foods are (1) inspection of the product, (2) voluntary statements on labels, (3) advertising, (4) the salesclerk, and (5) the relative price.

Inspecting the product. Although inspection of the product is a time-honored method of identifying quality in many foods, it has the distinct limitations discussed below.

(*a*) Identifying quality by inspection overemphasizes eye appeal, which may have little value as an indicator of the most important qualities in use. Unless one is skillful enough to recognize potato varieties and certain signs of maturity by sight, inspection tells one nothing about such a cooking quality as mealiness. Studies show that appearance is not a reliable indicator of tenderness in meat. Appearance is a fair indicator of the relative amount of preparation waste in some fruits and vegetables, but this is not always true, as in the case of hollow-heart potatoes, for example.

(*b*) Identifying quality by inspection requires skill, more of it than many homemakers ever acquire. The tendency is to overestimate the significance of simple qualities, color in oranges, for example, at the expense of variety characteristics which are related to such qualities as juiciness.

(*c*) Identifying quality by inspection is, of course, entirely inapplicable to products marketed in opaque packages. In the modern grocery store, particularly under the mass merchandising conditions of the supermarket, this eliminates the possibility of examination before purchase of most of the products one buys. The popular use of cellophane for the entire package or for a window in an otherwise opaque package is, to a certain extent, restoring the role of sight but not that of smell or touch.

(*d*) Identifying quality by inspection, of course, requires personal shopping which in turn requires time and effort which a homemaker may not have or wish to spend in this way.

Voluntary statements on labels as a source of information about the quality of foods. The only required statement on labels regarding quality is the designation "substandard" or "below standard in quality" when a standard quality has been established, as previously explained. But, if additional information is given, it must not be "false or misleading in any particular." So far as quality is concerned such additional information is usually of three types: (*a*) brand names, (*b*) descriptions, (*c*) grades.

(*a*) The purpose of a brand name is to identify a particular producer's product and differentiate it from similar products in order to lift it out of competition and thus promote its sale. It does not identify quality to the customer who is unfamiliar with it, but, if the producer maintains uniformity from package to package, it can serve, after a first trial, as a means of obtaining similar quality. Unfortunately, studies show that such uniformity cannot be depended upon. A canner may start out to develop a demand for a new brand of peas by maintaining uniformly high quality in the product the first year. The next season, any number of factors, some of which are outside his control, may cause him to reduce the quality of all or part of his pack. For example, on account of expanded demand or different weather conditions, the supply of peas of high quality may be inadequate. Or he may, within the limits of any claims made on the label and meeting the minimum standard for canned peas, decide to try to profit by reducing quality or uniformity or both. The general lack of discrimination by consumers and the absence of reliable methods of determining quality at the market minimize the penalties of such business practices.

For other reasons, brands are not satisfactory guides to quality for consumers. The number of them for most foods is so large that one cannot possibly become familiar with all. Many of them differ from store to store, which makes price comparisons of a given quality practically impossible even if uniformity within the brand could be assumed. Those with which one has become familiar in one locality may be unavailable in another. This gives a special advantage to nationally advertised products which are widely distributed, a fact taken into consideration in pricing them. The nationally advertised brands often sell for premium prices, while, side by side, private or unadvertised brands of similar quality may be marked

at considerably lower prices. Although it may be inconvenient to experiment, the efficient shopper will test the possibility that he may be equally well satisfied with a less expensive brand.

(*b*) Descriptions also have limited value in identifying quality. So long as the statements are truthful, a food manufacturer or distributor may give whatever information about the quality of his product he wishes or the size of the label permits. But it is difficult to make descriptions sufficiently specific to discriminate between products of different quality, even when the same person is preparing them and strongly desires to make them exact. When an individual food manufacturer or distributor describes his product, he is likely to choose deliberately words which are at least vaguely suggestive of superiority and which bear no particular comparative relationship to the terms used by another.

Furthermore, discriminating descriptions of the important quality factors are likely to be too complex to be useful to consumer buyers. For example, a descriptive labeling system for cream style corn has been suggested which includes five gradations in tenderness ("not tender," "firm, not tough," "medium," "tender," and "very tender") and three gradations in relative freedom from dark kernels and husks or silk ("to a high degree from," etc., "practically free from," etc., and "reasonably free from," etc.). Thus, differences in these two characteristics could result in fifteen different qualities without considering at least two more characteristics which are important in sweet corn quality, consistency and sweetness.

(*c*) Although grade labeling is not required, it is sometimes voluntarily practiced. Food buyers should show their appreciation of this service by buying the brands that offer it. When the government grade designations are used on labels they must conform to the standards to which they refer and hence are a relatively reliable indicator of quality.

Advertising as a source of information about quality. Although advertising of most types is subject to restriction as to its truthfulness, the problem of drawing a line between legitimate trade "puffing"—making the best possible claims for one's product which everyone expects—and reliable claims about quality is so difficult that this source of information must still be examined skeptically. Vagueness of the words used and the limited amount of significant facts offered also make it of less use than it might be as a source of information about quality of food.

The salesclerk as a source of information about quality. The same limitations which apply to the salesclerk as a source of information about the identity of a food apply here with even more force. However, some clerks know a great deal about the quality of their products, meat for example, and may well be consulted along with other sources.

The relative price as a basis for judging quality. Because market quality is defined on the basis of factors that affect demand, it might be assumed that a consumer buyer could use relative price as an indicator of quality. Though a general relationship between price and quality usually exists, it is far from being a close one in individual cases. Other factors exert a marked influence on prices of foods by the time the retail level is established. Among the more important of these are the costs of doing business in the particular store, the effectiveness of advertising in creating demand for a specific brand, and the presence or absence of strongly competitive products.

Deciding Where to Buy the Family's Food

The two principal types of marketing routes between the producer of food and the consumer are *direct routes*, which involve direct communication with the producer, and *indirect routes*, which generally involve buying from a retail store.

Direct Routes of Distributing Food. The methods of direct distribution of food include public markets, roadside stands, peddling, and parcel post. Methods of direct distribution, especially public markets and roadside stands, are important in many areas. Under nearly all conditions, direct distribution requires more effort on the part of the farmer than simple, wholesale deliveries at a country market. The prices he asks are higher than those which he would receive through the wholesale outlets, but the consumer expects that they will be lower than those asked at the retail store, unless the products are of superior quality. An exception to this general rule is milk, which can usually be purchased at a retail store more cheaply than when delivered, whether by a farmer or a specialized middleman. There is no indication that direct sales of food will increase substantially.

Indirect Routes of Distributing Food. If a consumer does not buy food directly from the farmer, he usually purchases it at a retail store. Retail stores may be classified in many ways:

According to services.
- Cash or credit.
- Carry or delivery.
- Self-service or clerk service.

According to location.
- The residential or neighborhood store.
- The shopping-center store.

According to type of stock.
- The full-line store including the supermarket which is a food department store.
- The staple grocery.
- The specialized food store, bakery, meat market, etc.
- The specialty shop, including the delicatessen, stocking "health" foods, fancy specialties, ready-to-eat foods, etc.
- The general store.

According to type of ownership.
- Independent.
  - Individual.
  - Voluntary chain.
    - Wholesaler-retailer type in which a group of retailers associate with a single wholesaler. Retailer-cooperative type in which a group of retailers set up their own wholesaling unit.
- Ownership (or corporation) chain: the wholesale and several retail units under the same ownership.
- Consumer cooperative: the retail and sometimes the wholesale division also owned by shareholding consumers who participate in profits on the basis of the amount of their purchases for the year.

In choosing between direct and indirect buying as well as among the different types of outlets of each, the efficient consumer buyer will consider:

1. The variety and quality of goods and services offered in relation to his wants.
2. The relative price charged for equivalent goods and services which he wants.

Comparisons of services offered may be made on the basis of the following considerations:

1. Is personal shopping required or can orders be placed by telephone?
2. How much time, effort, and transportation cost are involved in getting there?
3. Is delivery service available? Does it involve a special charge or minimum size of order?
4. Is credit available or must the bill be paid in cash?

5. Is clerk service offered or must the customer wait on himself and stand in line?
6. Is the stock carried sufficient in number and quality of products to meet his requirements?

Accurate comparisons of prices at retail stores require time and the facilities to identify quantities and qualities of products. In the absence of grade labeling, such identification is very difficult. Consequently, price comparisons tend to be made on staples, such as sugar, or on identical brands, especially the nationally advertised ones. Merchants recognize this tendency, however, and usually price such products more competitively than branded goods receiving more limited distribution in the locality. A better basis on which to select a store at which one will market regularly is to judge as nearly as possible which products are equivalent in quality and obtain prices at the stores being compared. Of course, if one has time to shop from store to store, purchases may be made on the basis of frequent price comparisons for individual foods.

Various investigations of food prices on a comparative basis indicate that the most important factors responsible for differences among retail stores are the *amount and kinds of service offered.* Delivery, credit, and extra clerk service are relatively costly services, and their elimination enables the retailer to make a substantial reduction in his margin. Carrying special items which have a low rate of turnover also increases costs.

Stores having relatively low gross annual sales have high costs of operation which make it necessary for their margins to be high. Mass merchandising as developed by supermarkets generally results in the lowest retail food prices because services are restricted and buying in volume is stimulated by giving price reductions when more than one package of an item is purchased and by making large-scale purchasing convenient. The latter is accomplished by placing all types of foods under one roof and by providing convenient parking space. Since the supermarket is an adaptation to the role of the automobile in modern life, location can often be in a low-rent area to provide another saving.

The first supermarkets were cooperative arrangements by independent food dealers—a staple grocer, butcher, fresh fruit and vegetable vendor, baker, etc., combining forces to locate under one roof. Later their innovations of arranging the store by departments and catering to large-scale buying were taken over by the corporation chains. Corporation chains had already pioneered in reduc-

ing costs of merchandising foods by restricting stores to those achieving an economical volume of sales, by supervising and training managers, by eliminating slow-moving items, and by combining ownership of wholesaling and retailing. Combined ownership made possible savings through buying, transporting, storing, and processing in very large quantities and by "streamlining" distribution channels. Thus the chain management performed for itself services of the middlemen who participate in other distribution systems.

Chains also reduced prices by featuring private brands as well as competing nationally advertised brands. Sometimes, they have assisted consumers in identifying quality by grade labels. Chain supermarkets generally offer the lowest prices of all retail food stores. Large-volume stores in general are usually the cleanest, most orderly, and best arranged to facilitate shopping.[6]

Large independent grocery stores or supermarkets may be able to compete with the chains offering similar services, because they have also adopted many of the mass merchandising practices developed by the former. Many small independents have been enabled to survive the competition of the chains by joining the "voluntaries" and by offering services which include convenience of location in a residential section rather than in a shopping district, and by carrying specialty foods. In general, however, prices are lower in ownership chains than in "voluntaries" or independently owned and operated stores, and the differences between prices in the voluntary chain store and in the independently operated one are, on the average, small.

The consumer cooperative type of retail food store requires a loyal membership of substantial numbers to ensure a volume of business sufficient to enable it to compete with the chain store. Successful "co-ops" usually mark their goods at "going" prices in order to avoid price wars. They return the profits to the member patrons on the basis of the amount of the individual patron's purchases rather than according to the conventional business practice of making such return on the basis of the amount of stock owned. The owners of shares in the "co-op" receive only a moderate rate of interest on their shares. Although cooperatives have played an important role in retailing food and other commodities in several European countries, they account for only a small fraction of the sales of food in most sections of the United States.

[6] Coles, *J. Marketing*, 10: 390 (1944).

The costs of marketing food usually take about half of the consumer's dollar. A question which might well be raised is whether the consumer has any responsibility for this wide margin. We have seen that reduction of services and large volume of sales are the most effective measures by which retailers reduce prices. If we encourage new retailers, especially small ones, by shifting our patronage to them or encourage new services by demanding or accepting them, do we not become responsible in the long run for higher costs of merchandising? Some authorities believe the answer to be "yes." [7] They maintain that competition in retailing does not promote reduction of prices as it does in manufacturing. The larger the number of retailers who service a given community, the larger the costs of doing business and the greater the tendency to offer new services to attract customers. The well-to-do minority who are willing to pay the costs of extra services tend to force the rest of the community to pay for them, too. If we want minimum food prices, we must not ask for or encourage extra services or division of the community business among a larger number of retailers.

Using the Foods Themselves Efficiently

We are a notoriously wasteful people in our use of food. Some of the waste takes place at the farm or in the course of manufacture and marketing and is therefore not subject to control by individual consumers. But the waste that takes place in almost every household is sufficient to deserve attention in the interest of efficiency. The following suggestions point out the more important causes of the latter waste and ways of eliminating it.

1. *Deterioration during storage.* Provide storage conditions which minimize deterioration in nutritive value, wholesomeness, and palatability.

2. *Wasteful methods of preparation.* These include discarding less attractive but edible portions such as outer leaves of a head of cabbage, the cooking liquids from vegetables, and the fat trimmed or fried from meat. These portions should be saved and eaten in some form.

3. *Using foods in unbalanced amounts when they are on hand in quantity instead of preserving them by appropriate methods.* This often happens in the case of perishables purchased in quantity or

[7] Black, *J. Farm Econ.*, 29: 616 (1947).

produced at home on a large scale. When a hog is butchered, for example, part of it should be preserved by freezing, curing, or canning, or it should be shared with a neighbor who will return in kind later, rather than eaten in unnecessarily large quantities over a short period.

4. *Wasting food at the table.* Edible food is left on the plate as a result of excessive variety in the menu, oversized portions, faulty preparation, or poor food habits. The remedies are obvious. In the case of fat from meat, table waste can be prevented by trimming before cooking, thus making it available for other uses.

5. *Inefficient use of leftovers.* If foods suffer further nutritive losses on reheating, or deteriorate in palatability if held or reheated, it is best to plan on a minimum of leftovers. It is worth while, however, to spend some time and effort on methods of utilizing such leftovers as inevitably occur with the best of planning.

PLANNING FOR ECONOMY OF LABOR AND MONEY IN THE DAY'S MEALS

Practices Which Promote Efficient Use of Labor

1. Plan several days' meals at one time.
2. Use a market order and shop on days and at hours when store business is generally light.
3. Use simplified menus and methods of preparation.
4. Use appropriate utensils and such generally labor-saving equipment as can be afforded.
5. Arrange the kitchen and equipment to provide efficient work centers for mixing, cooking, serving, and clearing away after meals.
6. Plan working procedures to save energy and time-consuming motions.
7. Prepare more than enough food for one meal if sanitary quality, nutritive quality, and palatability are not affected adversely.
8. Buy ready-to-eat or partially prepared foods when the saving in labor outweighs their extra cost.

Practices Which Promote Efficient Use of Money

1. Know about what it should cost to buy the food your family needs for health at existing price levels.
2. Know which foods are usually the best buys in terms of their nutritive values and use them extensively.

3. Read labels to find out what the food is, how much there is in the package, and, so far as the information is given, what is the quality rating of the food. Compare prices of different brands on the basis of cost per unit.
4. Buy foods in the lowest-priced quantities, provided they will not deteriorate before they are used.
5. Lay in supplies of nonperishable foods when prices are likely to rise, when they are seasonally low, in especially large market supply, or on special sale.
6. Buy the quality that is good enough but no better than needed.
7. Know the laws that protect food buyers and work for their enforcement and improvement.
8. Patronize low-price stores and do not demand special services.

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SECTION II

FOOD PROCESSING

Introduction

The Purposes of Food Processing

In this book the term processing will be used in a broad sense to cover all man-made changes in plant, animal, or inorganic materials used for food, whether they are brought about in the household or in a commercial establishment. The term technic refers to the specific method or procedure followed in making the alteration.

The origins of food processing are lost to us because they are older than the records of history. Probably the earliest methods of altering food materials consisted of separating and discarding inedible or difficult-to-masticate portions of plants and animals. The use of heat to make foods easier to eat followed. Drying by the heat of the sun or fire was a primitive method of preservation. Doubtless these and other technics came to be associated with increased appetite appeal early in human cultural development.

Modern food processing is characterized by increasing complexity of both purposes and technics. The purposes are associated with each of the criteria for appraisal and include:

1. Improvement in nutritive quality.
2. Improvement of digestibility.
3. Improvement of sanitary quality.
4. Enchancement or creation of appetite appeal.
5. Attainment of such economic advantages as preservation, mass production, standardization, and saving of household labor.

In both household and commercial processing, the achievement of one particular purpose may be at the expense of another. The most common examples involve increasing appetite appeal at the expense of nutritive quality. The application of scientific knowledge to minimize such conflicts should be a consideration of those who seek to improve industrial technics of food processing as well as of those who are teaching present and future homemakers, and will be a major consideration in this book.

The technics of food processing have developed as arts handed on from one generation to the next, with little understanding of the methods or reasons until very recent decades. The scientific literature in the field is for the most part so recent, and increasing at so fast a rate, that the volume produced since 1930 probably exceeds all that came before. It is consequently not surprising that, in the average household today, the methods of preparing and preserving foods are procedures which the cook has acquired from a variety of sources, most of them unscientific. In classifying food-preparation rules given by Mississippi homemakers, Dickins found only about 27 per cent of those reported by white homemakers under 40 years of age were in accord with practices based on scientific recommendations. A smaller percentage of those given by older women or Negroes were of this class. Many were based on old cookbooks and were out-of-date. Almost half of the rules given by each group seemed to have little or no relation to either scientific sources or old cookbooks.[1]

Competence is developed only after long practice, and a lack of understanding of the effects of the processes used causes irritating and apparently inexplicable "failures" even after years of experience. But more important than the recognized failures, which are primarily those in which palatability is at fault, are the more subtle culinary disasters in which a procedure causes marked damage to nutritive values, hidden hazards which may in time be responsible for hidden hungers if not for actual diseases. Examples of this type are numerous and will be given detailed attention in later chapters. They characterize commercial processing as well as that in the household; witness the nutritive deterioration in wheat flour resulting from the adoption of roller milling about 1875.

If an art is to become an exact science, it must become controllable and measurable in all its significant aspects. A science of food processing has evolved slowly because foods themselves and the effects of processes to which we subject them are complex. The number of variables to be controlled in an experiment in food processing is illustrated by the problem of determining the effect of varying one factor, such as the quantity of fat, on the palatability of a cake. The kinds and amounts of other ingredients, methods of manipulation, oven conditions, etc., have been estimated to reach a total of sixty to seventy-five variables to be controlled. Standardi-

[1] Dickins, *Miss. Agr. Expt. Sta. Bull.* 418 (1945).

zation of the manipulation is particularly difficult, and may require the invention of an appropriate mechanical substitute for the human hand in order to produce satisfactory duplication of results.

In spite of all difficulties, there have been enough studies in the field of food preparation to show that it may be scientific, just as medicine, engineering, and agriculture have become scientific. In relation to one great food industry, the manufacture of bread, it was said in 1922 that "bread is no longer a work of art—guesswork, at that, but an achievement of science built of selected materials combined by controlled processes, with no possibility of a poor product coming out of the oven." Breadmaking may have achieved scientific technics more rapidly than some other food processes, but there is no reason why we should not look forward to equal control and understanding of all food preparation.

In answer to the criticism that such control leads to standardization of food products, we say that this need not imply the elimination of catering to differences in tastes. As has been maintained in connection with standardization of breadmaking in America, the term *standardized* is not to be considered disparaging. "It is, on the contrary, intended to imply a tribute to the skill of American bakers and manufacturers of baking machinery who are responsible for the production of bread of uniformly high quality." However much the emphasis on volume of the loaf in commercial breadmaking may have resulted in a product considered by many inferior in palatability to that baked in the household, we must grant that the science and technology of baking have made it possible to secure uniformity in the qualities aimed at. If the possibility of greater profits should cause the commercial baker to desire a loaf of different properties, cereal chemists could doubtless enable him to go as far in its achievement. At any rate, the attainment of "uniformly high quality" is not in itself incompatible with individuality when that is desired.

Except where handling in very small lots is essential to secure high quality in the product, as seems to be the case with certain vegetables for example, the possibilities of expert supervision, the use of a great variety of processes and specialized ingredients, and accurate control of conditions give the industrial, large-scale producer important advantages in reducing food preparation to a science and in securing uniform quality at a low labor cost. The impartial critic must maintain, however, that much of present commercial food processing does not employ such advantages to turn out products of superior palatability. The prices of commercial food prod-

ucts of top quality are also frequently relatively high. Prices low enough to ensure competition with the household are often characteristic of products inferior to those made in the household under relatively uncontrolled conditions and with untrained labor. On all levels of quality, prices in terms of actual value are often inflated by such practices as excessive elaboration, sacrifice of nutritive qualities because of ignorance, carelessness, or conflict of their retention with qualities having higher sales appeal, and excessive merchandising costs resulting from high-pressure advertising and salesmanship. It seems probable that high quality in terms of nutrition, palatability, and wholesomeness at a cost level compatible with most family incomes will continue to encourage much household processing of foods. Furthermore, most families derive much satisfaction from the individuality of homemade products, and increasing leisure stimulates interest in food preparation as a hobby on the part of men and children as well as of the homemaker herself.

Fortunately, not all of our present knowledge of the science of food preparation is applicable to factory conditions only. It is now possible for individuals to secure sufficient knowledge of the changes produced by various types of processing in the household to enable them to prepare foods of uniformly high quality without a long period of trial and error or apprenticeship. To summarize this knowledge and to indicate ways in which it may be applied is the purpose of the rest of the book. In this section we shall describe major technics used in food processing with emphasis on those used in the household. These technics will be subdivided according to whether the major purpose of the processing is to make the food ready for immediate consumption—*preparation*—or to preserve it for future consumption—*preservation*.

CHAPTER 6

THE TECHNICS OF FOOD PREPARATION

Subdivision and fractionation in the preparation of foods.
Combining and mixing in the preparation of foods.
Heating in the preparation of foods.
Removing heat in the preparation of foods.
Use of chemicals in the preparation of foods.
Use of microorganisms in the preparation of foods.

The technics most commonly used in the preparation of foods may be classified under one of the following types: (1) subdivision and fractionation, (2) combining and mixing, (3) heating, (4) removal of heat, (5) use of chemicals, and (6) the use of microorganisms.

SUBDIVISION AND FRACTIONATION IN THE PREPARATION OF FOODS

Subdivision and fractionation in their simplest form were probably the types of processes used earliest in food preparation. As the terms indicate, the one refers to the separation of food materials into smaller units; the other refers to the separation of portions differing in some quality.

Some of the methods of processing foods which may be classed as subdivision or fractionation are:

Centrifuging. Promoting separation through the application of whirling force, as in the separation of cream from milk by use of a machine employing the centrifuge principle and known as a separator.

Cutting. Reducing to small pieces by means of a knife or scissors. When a similar result is obtained with a chopping knife or with a mechanical food chopper, the process is called *chopping.* Cutting into cubes is known as *dicing,* as in dicing potatoes. Cutting into very small pieces is *mincing,* as in mincing a piece of meat. *Shredding* is cutting into long, narrow pieces with a knife or a shredder, as in shredding cabbage.

Emulsification. Dispersing one liquid in another in which it is insoluble. If the dispersion is to be more than temporary, a *stabilizer* which coats the droplets of the dispersed phase must be incorporated.

Evaporation. Removal of water, commonly accelerated by heating.

Filtration. Separating solids from liquids by passage through fine-meshed materials, as in filtering fruit juices for jelly through a cloth bag.

Flotation. Separating on the basis of differences in specific gravity, as in the elimination of the overmature peas in a batch by use of brines of appropriate strength.

Grating. Reducing to small particles by rubbing on a rough surface, as in grating lemon peel.

Grinding. Reducing to small fragments by crushing, as in grinding coffee in a mill.

Homogenization. Subdividing large drops into smaller ones by forcing them through a small aperture under great pressure, as in homogenizing the fat in cream.

Milling. Reducing cereals to a flour by a succession of crackings or crushings alternated with sifting of the product, as in milling wheat flour by the roller process.

Paring. Removing surface layers by cutting, as in paring potatoes with a knife. When surface layers are removed by pressure of a knife edge rather than a cutting motion, the process is called *scraping*.

Peeling. Removal of an outer layer by stripping it off, by use of abrasion, water or steam, or caustics such as a lye solution.

Pressing. Separating liquid portions from solids by weights or mechanical pressure, as in making cider from apples.

Refining. Freeing any material from impurities, as in refining cane sugar.

Rendering. Separating fat from connective tissue by heat, as in rendering lard.

Skimming. Removing a floating layer by passing a utensil under it, as in skimming cream from milk.

Steeping. Extracting coloring, flavoring, or other constituents from materials by allowing them to stand in water which is usually held at a temperature just below the boiling point, as in steeping tea.

Some of these processes will be discussed in greater detail in connection with foods with which they are employed.

General Effects of Subdivision and Fractionation of Foods

The intelligent worker with foods should know how a process changes a food, not only in palatability but also in nutritive quality, digestibility, sanitary quality, and economy. Consideration of these qualities will be taken up in detail in discussions of the preparation of various foods in later chapters, but a few generalizations with examples should serve to impress upon the student the number of points of view to be employed in criticism.

Mere subdivision of a food does not change its nutritive quality, except when a vitamin is inactivated by the incorporation of air, but, since various parts differ in composition, removal of some particular part may result in a definite change. Thus, the fat of milk, which concentrates in a cream layer, takes a large proportion of the calorie value and vitamin A content of the milk with it if removed by skimming. In cereals, minerals and vitamins are most abundant in the bran and embryo portions which are lost in the by-products of white-flour milling.

Subdivision, which results in the exposure of more surface to the digestive fluids, speeds up digestion. Fractionation is frequently employed to remove the more indigestible portions of a food, as when bran is eliminated from milled wheat products.

Fractionation and subdivision may be employed to improve palatability. Grinding is often resorted to when products would otherwise be hard or tough in texture. Many times, one of the purposes of fractionation is to secure increased palatability by removal of less attractively flavored components, those actually disagreeable to the taste, portions giving coarseness to the texture, or those less attractive in appearance. Thus the skin of a banana is removed because its flavor is not pleasant, the pods of peas and the bran of wheat are rejected because their texture is not liked, and the outer leaves of a head of lettuce are discarded because they do not look so attractive as the inner ones. Fractionation may also remove portions more susceptible to deterioration through bacterial action, as in the refining of vegetable oils.

COMBINING AND MIXING IN THE PREPARATION OF FOODS

Food preparation often involves the combining and mixing of different foods or food materials. The following are the more common technics used:

Beating. Mixing materials by briskly lifting and dropping them with an appropriate tool. Sometimes used synonymously with whipping, as defined below.

Blending. Mixing two or more ingredients thoroughly.

Cutting. Usually the incorporation of fat in flour and other sifted dry ingredients with a knife, a method which produces relatively coarse division

of the fat and does not result in blending, as in cutting the fat into a pastry mixture.

Creaming. Softening fat by friction with a spoon, usually followed by gradual incorporation of sugar, as in cake making.

Folding. Mixing materials with an appropriate tool, usually a wire whip, by a careful lifting and dropping motion, as in folding whipped egg whites into a cake mixture. To be differentiated from stirring.

Kneading. Manipulating by alternating pressure with folding and stretching, as in kneading bread dough. A method of combination to the extent that it combines water and flour protein to make gluten.

Marinating. Coating the surfaces of food materials with a marinade, which is usually a mixture of oil and acid, as in marinating the components of a vegetable salad with French dressing.

Stirring. Mixing materials with an appropriate tool such as a spoon by a circular motion, as in stirring white sauce while cooking.

Whipping. Rapid beating with a wire whip or mechanical beater, usually to incorporate air, as in whipping egg white.

The most important effects of the methods of combining foods or ingredients are those related to palatability. Texture and flavor are often controlled to an important degree by the skill and method employed in combining component materials. Nutritive quality and other values are seldom altered by these technics, though the incorporation of air sometimes promotes the oxidation of vitamin C and may be an important exception.

HEATING IN THE PREPARATION OF FOODS

In the effects that it may have upon foods, processing by heating produces some of the most complex changes. Heat is a form of energy which matter possesses, owing to the vibratory or kinetic energy of its molecules. By temperature we mean intensity of heat. At temperatures above absolute zero (-273 degrees C.) all substances possess heat which is constantly being added to and subtracted from by transfer to and from other substances. When the inflow is greater than the outflow, the temperature of a given substance rises; under the opposite conditions it falls.

Methods of Transferring Heat

The three fundamental ways of altering the temperature of a substance are conduction, radiation, and electrical currents.

Conduction

The temperature of a substance is always influenced by the temperature of any matter in contact with it. When a substance is in contact with another of a higher temperature, the kinetic energy of the molecules of the former is increased, its molecules are thrown into more violent motion, and we say it has been heated. At the same time the kinetic energy of the molecules of the second substance is lowered and we say it has cooled. This process of direct transfer of heat by contact is commonly called conduction. The speed with which a substance is heated by conduction depends upon such factors as its conductivity, the extent of the area of contact with the hotter material, and the relative temperature of the hotter material.

The conductivity of cooking utensils and the cooking medium affect the speed of cooking. Copper has the highest conductivity of metals commonly used for utensils. For this reason it is often employed as the outer layer on less conductive metals such as stainless steel. Aluminum is also a much better conductor than steel and is likewise used as an inset in the bottom of some steel utensils. Glass is a very poor conductor of heat but, as discussed later, it is an excellent transmitter of radiant heat.

As cooking media, water and steam are better conductors of heat than air, but all three are much less effective than metals. The relation of the cooking medium to the rate of heating will be discussed in more detail later.

The area of contact with the source of heat is important in heating by conduction. When only limited areas of the bottom of a pan are in contact with the source of heat, they become hotter than the rest of the pan bottom and tend to scorch the food. In cooking with a very small amount of water it is important to have a pan bottom that heats evenly. Thick, flat bottoms tend to do this because they distribute the heat well and do not warp or dent easily.

If liquids or gases are being heated, conduction is facilitated by the development of convection currents. In matter in these states, the portions nearest the source of heat, which are the first to become warmer and consequently less dense, rise and are replaced by colder, denser portions. Though similar differences in density arise when solids are heated, it is obvious that convection currents cannot assist in the distribution of the heat because movement of the material is

impossible. Solids are the best conductors of heat, however, because their molecules are closer together than those of matter in other states.

Radiation

In addition to the direct transfer of kinetic energy of one thermally agitated molecule to another, which is conduction, energy in the form of certain electromagnetic radiations may produce heating. Electromagnetic radiations are composed of packets of energy ("quanta") which vibrate at high frequencies and travel through space at tremendous speeds. Characteristic effects vary with the vibration frequency of the waves which range in decreasing rate of frequency as follows: cosmic rays, gamma rays, X-rays, ultraviolet waves, visible light, infrared, radio, and sound waves. Of these, the infrared are most important in cooking; the use of radio waves is in an experimental stage.

At temperatures above absolute zero some of the heat of a substance is constantly being transformed into electromagnetic or radiant energy. Whenever this energy is absorbed by a substance, it produces agitation of the electrons and the increased molecular motion which is heat. If the substance receives more radiant energy than it is emitting, its temperature rises. Conversely, if it emits more radiant energy than it receives, its temperature falls. It is in this form that the energy of the sun reaches the earth.

Radiant energy can traverse the best vacuum ever constructed. It must be absorbed, however, if it is to alter temperature. With ordinary cooking equipment the greatest amount of radiant energy is supplied by open flame or glowing metallic broilers. The wavelengths are in the infrared zone. Smooth, shiny, metallic surfaces reflect infrared waves; dull, rough surfaces absorb them. Glass (Pyrex) transmits infrared readily. Whether these radiations reach the food directly or through glass, only the surface is heated by them because they do not penetrate below it. Rise of temperature within the food is produced by conduction.

So-called "infrared broilers" are wires heated to very hot temperatures by electricity so that a high intensity of infrared radiations is produced. Cooking with infrared lamps is in an experimental stage. These bulbs contain tungsten filaments which reach a temperature of about 4200 degrees F. (2316 degrees C.) and convert less of the electrical energy into waves of higher frequencies that give visible

light than do ordinary light bulbs. If the infrared bulb is placed under the food container, glass must be used if the food is to receive the radiations. Surface heating of the food is very rapid as compared with the internal transfer by conduction and produces a type of cooking which is especially adapted to browning surfaces and developing flavors without overcooking the interior, as in broiling meat or toasting.

Cooking with radio waves, commonly called radar cooking, is also in an experimental stage. The waves are generated by special electron (magnetron) tubes powered by ultra-high-frequency electricity (a billion or more cycles per second). These waves are much longer than the infrared and, when focused on food in a specially constructed oven, penetrate it much more deeply. In meat, penetration to a depth of 2 or 3 inches has been reported, but the distance is less as the frequency of the waves is increased. To the depth to which the waves penetrate, the food cooks very rapidly and evenly without surface browning or crust formation.

Heating Foods by Electrical Currents

Several types of heating foods by electrical currents are in an experimental stage. They include *electrical conduction heating, electrical induction heating*, and *dielectric heating*. Both electrical conduction heating and electrical induction heating depend upon the capacity of certain foods to serve as conductors of electricity. Dielectric heating depends upon the relative resistance of foods to the conduction of electricity. Thus foods differ with respect to the type of method which works best. In general, heating with electrical currents is not a result of the transfer of heat from a warmer source as are conduction and radiation. Instead, the heat is generated within the food itself, and the interior heats as rapidly as the exterior. Consequently, as in radar heating, exterior browning and crust formation do not take place.

In electrical conduction heating, the food is placed between two plates or electrodes and the current is sent through it. This method does not work well with most foods because they shrink as they are heated, thus breaking contact with the electrodes. The resultant arcing of the current burns the food surface where the arcing takes place.

Electrical induction heating involves placing the food in the varying magnetic field produced by sending alternating current

through a wire coil surrounding it. Fast cooking by this method requires alternating current of very high frequency which can be used with only small coils. Also it is difficult to concentrate the magnetic field in the food.

Dielectric heating of food is produced by placing the food between two electrodes, one of which is positive and attracts electrons in the food, and the other of which is negative and attracts the protons. Very high-frequency alternating current of the order of 25 million cycles per second and very high voltage are required for rapid cooking. The reversals of pull on the electrons and protons strain the molecules, causing heating by mechanical friction.[1]

Methods of Cooking Used in Food Preparation

Heat is used in the food preparation processes of cooking and toasting. Cooking is the term applied when heating affects the entire mass of the food, whereas toasting concerns primarily the effects of heat on the surface. The changes produced in foods by heat depend upon such factors as the method of heat transfer, the time of heating, and the temperature reached on the surface and within the mass of the food, as well as upon the nature of the food itself.

In practice, the methods of cooking may be classified according to the cooking medium, which may be (1) air, (2) water, (3) steam, (4) fat, and (5) a combination of one or more of the preceding. In electronic cooking, where heat is generated within the food electronically, there is no cooking medium.

Methods in Which Air Is the Principal Cooking Medium

The methods in which air is the principal cooking medium are: (*a*) broiling, and (*b*) roasting and baking. *Broiling* is cooking over or under a source of direct heat such as a gas burner or glowing electric unit. Much of the heat is derived from radiant energy; some is conducted from the air and from the broiler rack. *Roasting* originally meant cooking on a spit before an open fire or by covering with hot coals, but now the term is used synonymously with baking in essential meaning, though it is usually restricted to meat cookery. *Baking* is cooking by dry heat, now usually in an oven. In all oven

[1] See Kinn, *Food Technol.*, 1: 161 (1947). Also Proctor and Goldblith, in *Advances in Food Research*, edited by Mrak and Stewart, Academic Press, New York, 1951, Vol. III, p. 120.

cooking, convection currents in the air aid in heating the air itself and in equalizing the oven temperature. When foods in an oven are in a covered container, heat is received by conduction on all parts in contact with the container; steam is the cooking medium for the rest. Glass transmits some radiant energy, depending upon its wavelength, but metal pans absorb these waves and transmit the resulting heat by conduction wherever material of a lower temperature is in contact with the food. Where the pan or its cover is not in contact with the food, the heat is re-radiated to the food. Perhaps the differences in surface texture in foods cooked in different types of containers are in part explained by the kind of heat transfer.

The cooking temperatures for most oven cooking range from 250 to 500 degrees F. (120 to 260 degrees C.). When air is the principal cooking medium, ease of securing the appropriate cooking temperature depends upon such factors as the intensity of the heat applied, the effectiveness of the oven insulation, and the amount of water vapor present.

Methods in Which Water Is the Principal Cooking Medium

The methods of cooking in which water is the cooking medium are (*a*) boiling, (*b*) simmering, and (*c*) stewing. *Boiling* is cooking in a bath of water at the boiling point. This temperature may be recognized by the presence of many bubbles of steam rising to the top and breaking. Incomplete cooking by boiling is called parboiling. It is used when another method is to be employed for the remainder of the cooking, or when strong-flavored or other water-soluble constituents are to be removed and fresh water added for continued cooking by boiling. *Simmering* is cooking in a bath of water somewhat below the boiling point, 180 to 210 degrees F. (82 to 99 degrees C.). This range may be recognized by the presence of bubbles of steam which disappear before they reach the surface. It is almost impossible to maintain these temperatures on ordinary heating equipment except with a double boiler. *Stewing* is cooking in water to cover, which may be either simmering or boiling.

On all sides in contact with the container, water probably receives heat only by conduction. Water is a poor conductor of heat in comparison with metals, but convection currents tend to equalize the temperature within its volume.

Among a number of qualities which peculiarly affect the behavior of water as a cooking medium is its high heat capacity, the highest

of any known liquid. More heat must be applied to raise its temperature than is necessary with an equal amount of any other liquid. This means that comparatively large quantities of heat must be absorbed when it is used as a cooking medium.

Another important characteristic of water is its comparatively high boiling point, 212 degrees F. (100 degrees C.), appreciated by one who has tried to duplicate at mountain altitudes procedures successful nearer sea level. The effect of reduced pressure at high altitudes upon the boiling point of water is shown in Table XIV. Thus

Table XIV. The relation of the boiling point of water to altitude

Altitude, feet	Temperature at boiling	
	Degrees C.	Degrees F.
Sea level	100	212.0
1025	99	210.2
2063	98	208.4
3115	97	206.6
4169	95	203.0
5225	94	201.2
6304	93	199.4
7381	92	197.6
8481	91	195.8
9031	90	194.0

on the top of Mt. Blanc water boils at 183 degrees F. (84 degrees C.) and on Pikes Peak at 192 degrees F. (89 degrees C.). These boiling temperatures markedly extend the time required for doneness in cooking many foods, and in some cases, flour mixtures containing egg, for example, mere extension of time does not achieve satisfactory results.

The boiling point of liquids may be raised by addition of nonvolatile solutes. One formula weight of a non-ionized substance in 1000 grams of water causes an elevation in its boiling point of 0.94 degree F. (0.52 degree C.). Ionization increases this effect in proportion to the number of ions present. Thus, completely ionized sodium chloride exerts twice the effect of sugar per formula weight. To raise the boiling point of water baths used in canning, calcium chloride has been recommended. It raises the boiling point about three times as much per gram molecular weight as an un-ionized compound. Calcium chloride solution is corrosive, however.

Methods in Which Steam Is the Principal Cooking Medium

The methods of cooking in which steam is the cooking medium are (*a*) steaming, (*b*) "waterless" cooking, and (*c*) pressure cooking.

Steaming usually refers to cooking in the steam arising from added water, and waterless cooking to cooking in steam formed from the water originally present in the food. Placing foods in bags improvised from sheets of a special parchment paper and then placing them in boiling water is also a form of waterless cooking so far as the foods themselves are concerned. By this method, different foods wrapped separately may be cooked in the same pan without exchange of flavors, and foods such as fish, which are difficult to handle without breaking up after they are cooked, can be transferred to a serving dish more easily.

In ordinary containers where the pressure is that of the atmosphere, the temperature of steam is that of boiling water. The continuous formation of steam requires a relatively high heat input. Whereas 1 calorie * is required to raise the temperature of 1 gram of water 1 degree C., 540 calories must be added to change one gram of water at 100 degrees C. into steam at the same temperature. Additional heat causes no further rise in temperature unless the steam is confined under pressure as in a pressure cooker or pressure saucepan. In an open pan or loosely covered container, steam escapes, leaving room for additional steam of the same temperature to take its place.

Cooking with steam under pressure is known as *pressure cooking*. When steam is held under pressure, the heat of vaporization is not lost and the temperature rises. In Table XV the temperatures avail-

Table XV. Temperatures at different pressures in a pressure cooker at sea level

Pounds of pressure above atmospheric pressure at sea level	Temperature	
	Degrees F.	Degrees C.
0	212	100
5	228	109
10	240	116
15	250	121
20	259	126
25	267	131

* The gram calorie, or small calorie.

able in a pressure cooker at sea level are listed. About 1 pound pressure for each 2000 feet above sea level must be added to give corresponding temperatures. The high temperatures reached in cooking with steam under pressure markedly shorten the time required.

In all forms of steaming, heat is conducted from the steam to the food. Also, as long as the food surface is below the boiling point, additional heat is released by condensation of steam on the cooler surface. Heat transfer in baking may resemble that in a steamer when a food high in water is cooked in the oven. Although the steam formed from the moisture in the food may release part of its heat by condensation on the food, the total amount of heat required to produce the evaporation may be so large that the oven temperature fails to rise to the point ordinarily produced by a given heat input. This is the probable explanation when a flour mixture such as muffins fails to brown if baked in the presence of meat or a similar moist food.[2]

Methods in Which Fat Is the Principal Cooking Medium

Fat is used as the cooking medium in frying. The amount of added fat may vary from none as in *pan broiling* to an amount sufficient for immersion as in *deep frying*. In pan broiling, griddle cooking, and grilling, fat melted from the food itself conducts heat from the pan to the food and prevents sticking. The term *sauté*, which literally means "jumped," is sometimes applied to cooking in a lightly greased pan which permits one to "flip" the product. Pan frying is frying in a larger amount of fat which is not enough to cover the food. As in pan broiling and sautéing, the food must be turned over for complete cooking.

In deep-fat frying, as in boiling, a liquid cooking medium receives heat by conduction from the pan and distributes it by convection currents. The temperature to which fats can be heated is not limited by a boiling point, however, but by a point at which they decompose with the formation of free fatty acids and glycerol. The temperature at which this change takes place is indicated by the presence of visible fumes. These fumes contain an irritating substance called acrolein, which is formed from the glycerol of the decomposed fat molecules. The point at which the fumes appear is called the *smoking temperature*. Fats and oils should not be heated to this point when used for frying. Since the temperatures required

[2] Monroe, *J. Home Econ.*, 36: 99 (1944).

for frying run as high as 385 degrees F. (196 degrees C.), fats with smoking temperatures below this are not desirable for such use.

Directions in older recipes often specified the addition of the food to the heated fat when smoke appears. Cold food lowers the temperature so much that the extra heat does not necessarily cause too rapid cooking on the surface, but it is a much better practice from the standpoint of preventing decomposition to use a thermometer and avoid heating to the smoking temperature. The frying qualities of different fats will be discussed in Chapter 13.

Methods of Cooking in Which More Than One Medium Are Used

Braising and fricasseeing, terms now often used synonymously and applied to meat and poultry, represent a combination of sautéing and subsequent cooking in a small amount of liquid in a covered utensil, a form of steaming. *Pot roasting* is the term commonly used when a large piece of meat is cooked by this method.

In *fireless cooking* an initial period of direct heating is followed by a relatively long, slow cooking by indirect heat which has been accumulated from a direct source. The indirect source is often a soapstone. Both food and soapstone are first heated on a stove, then transferred to an insulated box where cooking continues slowly. Electric "fireless" cookers are now available. In these, the food and heat storage elements are heated by an electric unit which is then turned off or to a very low heat. Cooking continues through the agency of stored heat, as in the true fireless cooker. Fireless cooking may begin at a boiling temperature, but it gradually decreases.

Some electric ranges are supplied with an insulated well built on the fireless-cooker principle. The food is placed in the well, given a preliminary period of heating, and then, with the current turned off or very low, cooking continues. In the latter case, boiling or simmering may persist.

Methods of Cooking in Which There Is No Cooking Medium

In dielectric cooking, probably the most promising type of cooking directly by electrical current, there is no cooking medium other than the food itself. The current is carried to the food by electrodes covering two opposite surfaces. A utensil may be used but only to catch the drip, because other materials placed between the electrodes and the food would usually interfere with the action of the current.

Homogeneous foods tend to be heated uniformly and rapidly by this method in one-third or less of the usual time. Equipment for such cooking is still in an experimental state and has not been adapted to household use.

General Effects of Cooking

Periodically, cults of fanatics urge a return to the eating of raw foods. It is true that our newer knowledge of the importance of vitamins and the susceptibility of ascorbic acid and thiamine, in particular, to inactivation during heating furnish a scientific basis for advocating the consumption of some uncooked foods. Also, heat may alter nutritive quality in other ways. The value of protein to the body may be reduced, depending upon the time and temperature of heating, the proportion of moisture in the food, and whether a reducing sugar such as dextrose is present. In some cases, the linkages binding essential amino acids in the protein molecule become more resistant to digestion. In others, biological value is reduced by decomposition of the essential amino acid lysine. In the presence of dextrose, a reaction between this sugar and certain essential amino acids destroys their biological usefulness. Thus toasted breakfast foods and bread have reduced protein value. Fortunately, heating a baby's formula after dextrose is added (in corn sirup, for example) is not extensive enough to injure the protein.[3] The heat that bean proteins receive in ordinary cooking actually increases their digestibility.

When water is used as a cooking medium and discarded, valuable water-soluble constituents such as sugar, salts, and water-soluble vitamins are lost.

In spite of the possibility of losses in nutritive value, heating food has certain advantages. In a sense, all the processes of cooking are processes of digestion, because they may involve such disintegrative chemical changes as transformation of starch into dextrins and disaccharides, the partial hydrolysis of certain proteins in the connective tissue of meat, and the partial splitting of the fats. In addition, small amounts of cellulose may be hydrolyzed sufficiently by heat to become digestible in the human alimentary tract. Even when this is not true, the heat may have softened the cellulose walls of cells in plant materials so that other constituents are more readily digested because permeability to digestive fluids is facilitated.

[3] Hodson, *J. Am. Dietet. Assoc.*, 27: 488 (1951).

Palatability in a cooked product, so far as taste is concerned, may be secured by changes in flavor, as in meat; by blending of flavors, as in a cake; or merely by conservation of flavors associated with delicate substances which are easily lost by volatilization or by destruction, as in many vegetables. The desired change in texture may be either a softening, as in fruits, or a hardening, as in flour mixtures, and others almost as diverse as the number of foods themselves. Securing desirable color in heated products may be a problem of conservation, as in spinach, or one of change, as in meat.

Interior temperatures reached by many foods in cooking can be relied upon for destruction of pathogenic organisms. Probably many of the headaches, attacks of constipation, diarrheas, feelings of fatigue, etc., from which we suffer and which may be so ill-defined in their onset, so general in their symptoms, and so gradual in their disappearance that their origin is often incorrectly referred to other causes, are caused by the consumption of infected food. In minimizing chances for such infections, cooking is an important aid to continued well-being, especially when applied to foods particularly susceptible to contamination.

REMOVING HEAT IN THE PREPARATION OF FOODS

When foods are processed by cooking, the problem is one of transferring heat to the food in such amounts that the temperature of the food rises. The opposite procedure, removal of heat by its transfer to cooler bodies in such quantities that the temperature of the food is lowered, is also employed in food preparation. Cooling in the range above freezing may require refrigeration. Freezing temperatures may be produced by either ice-salt mixtures or by mechanical freezers.

Refrigeration

The term "refrigeration" will be used here to refer to the production of cold temperatures by artificial methods. Three methods of refrigeration at temperatures above freezing are used in handling foods. These are (1) so-called ice-less refrigeration, (2) ice refrigeration, and (3) mechanical refrigeration.

Iceless Refrigeration

When water is evaporated, heat is removed from the environment at the rate of 540 calories per gram of water vaporized at 212 de-

grees F. (100 degrees C.), as previously mentioned. This is the principle of iceless refrigeration, a simple example of which is afforded by placing a bottle of milk in a shallow basin of water and wrapping it with a wet cloth which extends into the water. When the air is dry and in motion, a pronounced cooling effect may be noted.

The same principle may be utilized on a larger scale by building an iceless refrigerator, a frame of desired size covered with wire netting and a cloth which extends into pans of water above and below. If such an apparatus is placed in a shady spot where the air circulates freely, it furnishes a decidedly cooled interior.

Ice Refrigeration

When ice melts, it absorbs heat at the rate of 80 calories per gram, in contrast to the 1 calorie * per gram absorbed for each degree centigrade rise in temperature when water is warmed. Consequently, it is relatively efficient to reduce temperatures in insulated spaces. A well-insulated refrigerator iced to at least three-quarters of its capacity may maintain a temperature of 40 degrees F. (4.4 degrees C.) in the milk compartment and 48 degrees F. (8.9 degrees C.) on the top shelf. When insulation is poor, the room temperature is high, large quantities of food at room temperature or above are introduced, the doors are opened and closed frequently, or the quantity of ice is low, the temperature rises.

Mechanical Refrigeration

Mechanical refrigeration is based on the principle that liquids absorb large amounts of heat from the environment when they pass over into the gaseous state, the same principle used in iceless refrigeration. In mechanical refrigeration, a gas, such as freon, is liquefied by pressure and run through coils in the cooling chamber of the refrigerator, where it is vaporized and superheated by heat from the interior and its contents. Finally, in the compression type of refrigerator, electric power is utilized to re-liquefy the gas by compression. This method of refrigeration may be controlled to cause temperatures which are several degrees below freezing in special compartments, and a flexible range of temperatures for food being held in the other storage spaces.

In general, mechanical refrigeration produces the coolest non-

* The gram calorie, or small calorie.

freezing temperatures, but, for the household, initial cost is high and depreciation uncertain. Economy of operation depends upon local cost of power, external temperatures, and such management factors as the amount and temperature of food put into it, and the frequency of opening the door.

Freezing

Freezing has become one of the most popular methods of food preparation. The types of freezing processes in common household use are (1) freezing by use of mixtures containing ice, and (2) freezing by means of low-temperature mechanical refrigeration.

Freezing by Use of Mixtures Containing Ice

A mixture of ice and pure water gives a temperature of 0 degrees C. (32 degrees F.). This temperature may be reduced by the addition of any substance which will dissolve in water, the amount of the reduction depending upon the number of units in the solute. Thus, materials which ionize make the most efficient freezing-point depressants. One gram formula weight of a non-ionizing substance dissolved in 1 liter of water lowers the freezing point 1.86 degrees C. (3.3 degrees F.). Ionizing compounds have greater effects, depending upon the extent of ionization. Ordinary sodium chloride is commonly employed as the freezing-point depressant in freezing mixtures used in home processing. The relation of the quantity of salt present to the temperature of the freezing mixture is shown in Figure 2.[4] It is evident that ice and salt may be utilized to freeze foods of which the freezing point is many degrees lower than that of water.

Mechanical Freezing

Most modern mechanical refrigerators contain a compartment which maintains or can be set to give temperatures which will freeze food mixtures. Deep freezers which are designed to freeze and store foods for the purpose of preservation may also, of course, be employed in the preparation of foods to be eaten in the frozen state. As yet it has not been conclusively demonstrated that the nutritive quality of foods is influenced by cooling and freezing in themselves, though storage, especially at temperatures above freezing, may re-

[4] Bowen, *U. S. Dept. Agr., Bull.* 98 (1914)

sult in a loss of vitamin C. Digestibility is probably unaffected by freezing and cooling.

We prefer foods intended to be hot to be served hot, and foods intended to be cold to be served cold. Refrigeration and other forms of cooling aid in developing palatability from this aspect. Freezing contributes interest in the form of a greater extreme in temperature than that produced by cooling above the freezing point, and an interesting variety of texture sensations.

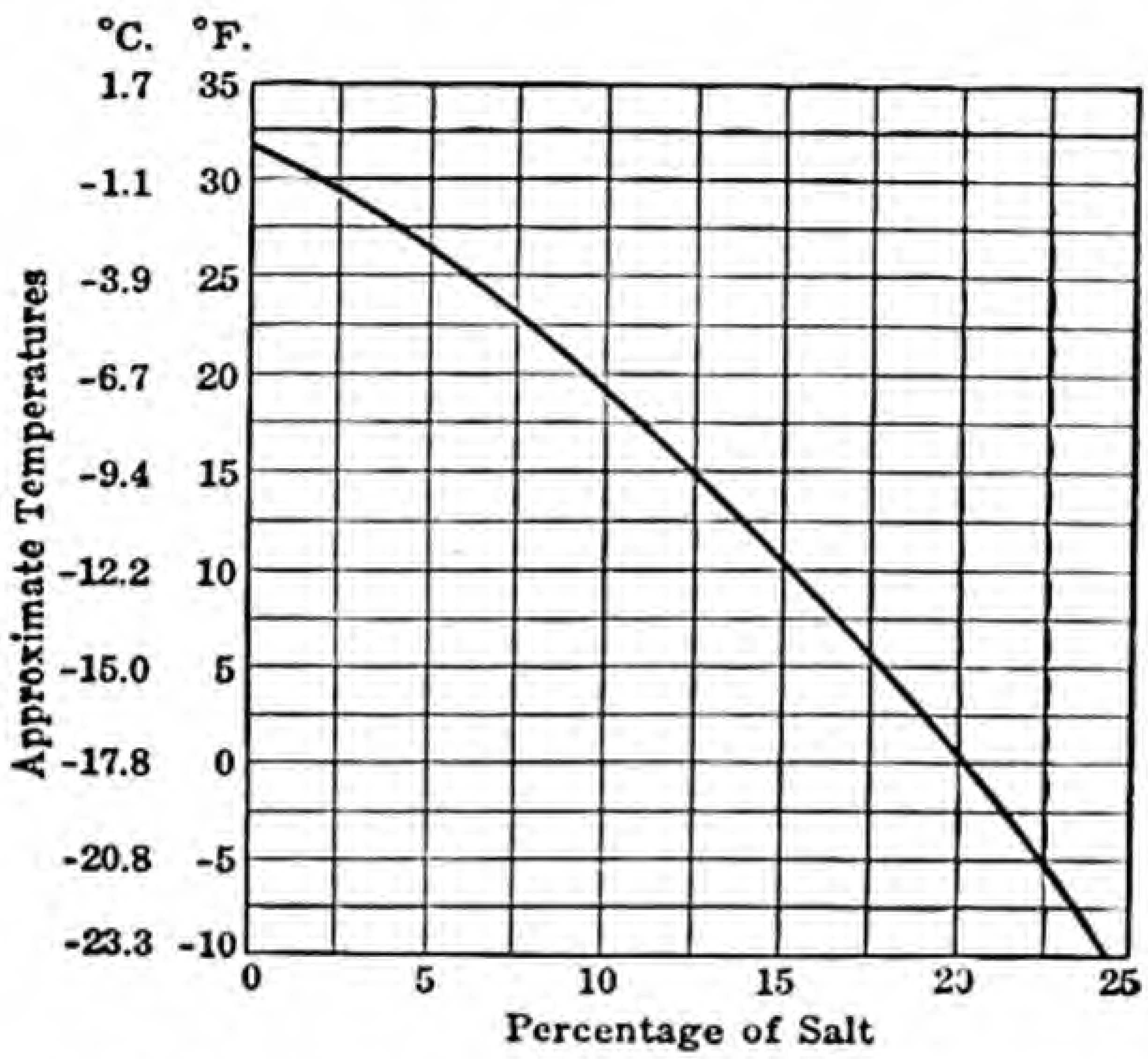

FIG. 2. Approximate temperatures obtained with different proportions of salt in ice and salt freezing mixtures. (*After Bowen.*)

Cooling and freezing retard the multiplication of bacteria but cannot be relied upon to kill them.

USE OF CHEMICALS IN THE PREPARATION OF FOODS

Subdivision and fractionation, combining and mixing, heating and removing heat are physical processes employed in food preparation. They may or may not cause chemical changes. Chemical technics, on the other hand, involve the addition of specific substances which react to produce specific chemical changes. Examples of such chemical technics commonly employed in the household include (1) the use of sodium bicarbonate to react with accompanying acid or acid present in a food ingredient to produce carbon

dioxide for leavening, (2) use of vinegar or other acid-containing ingredient such as tomatoes to accelerate hydrolysis of the connective tissue in tough cuts of meat, (3) addition of cream of tartar to candy mixtures to accelerate inversion of sucrose, (4) addition of rennet tablets to milk to coagulate it.

In commercial food processing, chemical technics are employed much more frequently than in the household, and, as mentioned in Chapter 3, constitute one of the major problems of public health officials charged with the safeguarding of our food supply. The principal function of chemical technics in food preparation is to produce desired palatability changes, especially changes in texture. They may or may not be detrimental to nutritive quality; an excess of soda increases the inactivation of thiamine in flour mixtures or of ascorbic acid in green vegetables when it is added to enhance their color.

USE OF MICROORGANISMS IN THE PREPARATION OF FOODS

Microorganisms which are useful in food preparation may be present naturally in a food or a particular ingredient. In such cases all that is needed is to provide suitable conditions for their development. In other cases the appropriate organisms may be added independently. Examples of changes brought about by microorganisms in household food processing include: (1) the souring of milk for use in cooking or cheesemaking, (2) the addition of yeast to flour mixtures to produce carbon dioxide from sugar. Biological technics of this type are employed more extensively in commercial food processing than in the household on account of the skill and technical knowledge required for their success. Their major function is usually to achieve some desired palatability quality.

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combined to make this method of food preservation of increasing significance for the average family.

Freezing as a technic of food preservation has three phases: (1) prefreezing treatments, (2) freezing, and (3) frozen storage. Prefreezing treatments vary with the product and include blanching, concentration, addition of other materials such as sugar, sirup, ascorbic acid, citric acid or sulfite, and packaging.

Blanching, used primarily with vegetables, is scalding in steam or hot water, usually followed by immersion in cold water to terminate the cooking action and to precool the product. Besides destroying enzymes which would otherwise cause deterioration, it gives the product an additional wash, makes it possible to remove skins where that is desired, and shrinks bulky types so that they require less space.

Fruits with cut surfaces may require the addition of some substance which retards enzymatic browning, most pronounced during thawing. Blanching is not applicable because it damages delicate, volatile fruit flavors. Treatment with sulfur dioxide or a sulfite dip, packing in citric acid solution, or adding ascorbic acid to a sugar sirup when it is used, is effective. Sugar sirup alone is helpful because it shuts out air. Besides improving color and flavor, it also tends to protect the original ascorbic acid in the fruit. Dry sugar has about the same effect because it makes its own sirup by draining juice from the fruit.

Commercially, fruit juices are concentrated by freezing in a vacuum. Naturalness of flavor is enhanced by overconcentration and restoration of desired volume with fresh juice.

In general, rapid freezing of plant or animal tissues results in the formation of many small ice crystals, both within the cells and in the intercellular spaces. When the tissues are thawed, there is minimum cell-wall destruction and tissue alteration. On the other hand, slow freezing produces large ice crystals in the intercellular spaces which may puncture the cell walls and dehydrate the contents. Such tissues tend to leak on thawing and become flabby. Under ordinary conditions, however, wide differences in rates of freezing fruits and vegetables do not seem to produce noticeable differences in appearance, texture, taste, or vitamin content, but the entire package should be frozen in not more than twelve hours, or deterioration will be evident.[1]

[1] Lee et al., *Ind. Eng. Chem.*, 38: 341 (1946). Also Lee et al., *Food Technol.*, 3: 164 (1949).

In the freezing of flesh foods, rapid freezing with the production of smaller crystals and their formation within the cells does appear to have advantages. Intrafiber crystals stretch and otherwise weaken the connective tissue in the cell walls; this increases the tenderness of the cooked product. Such crystals are also more completely resorbed during thawing, thus tending to reduce thawing drip.[2] Small steaks with their larger cut surfaces, however, show this effect to a higher degree than large beef roasts or whole birds, both of which may differ little in drip as related to freezing temperatures. In fact, there appears to be little or no evidence that, under ordinary conditions for quick freezing, differences in speed of freezing noticeably affect the palatability of the cooked food.[3]

Factors other than the size of crystals also affect the amount of drip. Although the ice crystals formed in ripened meat are larger than those formed in freshly slaughtered meat frozen under similar conditions, the ripened fibers resorb the water more completely and hence such meat has less thawing drip. Beef is more susceptible to drip than veal, lamb, or pork.

In general, the colder the frozen storage, the better the preservation. For this reason, special deep freezers for household use are superior to freezing compartments in mechanical refrigerators. For holding even a few days, the storage temperature should be at least as cold as 10 degrees F. (−12 degrees C.), and if the time is to be extended to four months or longer the temperature should not exceed 0 degree F. (−18 degrees C.). Any good household freezer provides this temperature, but dual temperature refrigerators often do not. Frozen foods held at temperatures below 15 degrees F. (−9 degrees C.) do not become unwholesome as a result of microbial action, but chemical and enzymic changes which affect taste, color, and ascorbic acid retention unfavorably may develop.[4]

Fluctuation of freezing storage temperatures may also injure palatability. If the temperature rises, the smaller ice crystals thaw first. When the temperature falls, this water freezes out on the larger unthawed crystals or appears as frost on the exterior of the food. This results in greater drip loss in thawing and reduced juiciness in the food. Such frosting is commonly observed when frozen food is held in the ice-cube compartment or in the freezing

[2] Hiner et al., *Food Res.*, 10: 312 (1945).

[3] Lee et al., *Food Res.*, 15: 8 (1950).

[4] Tressler, *Prac. Home Econ.*, 29: 27 (1951).

compartment of dual-temperature refrigerators and indicates that the temperature is too high for more than brief holding.

Directions for household freezing may be obtained from most state agricultural extension services and from the BHNHE.

Dehydration

The development of microorganisms in many types of foods can be sufficiently inhibited by the removal of water to make this an effective technic for food preservation. Water may be removed by heating or by freezing in a vacuum, a process known as freeze-drying or dehydrofreezing. Inability to retain natural palatability qualities in many dried foods has limited the use of most forms of dehydration except in such emergencies as war or large-scale government purchase of "surplus" farm commodities. Under these conditions, the relative economy of dehydration as a process, and of the storage or shipment of the product, has outweighed its disadvantages. Dehydration is a little-used method of household preservation but is employed to a significant extent commercially for fruits, eggs, milk and skim milk, meat, and vegetables.

Heat for dehydration may be supplied by the sun, by an artificial source, or generated within the food electronically. Sun drying is limited to fruits such as prunes, peaches, apricots, figs, pears, raisins, currants, and bananas. For a large proportion of these products artificial dehydration has superseded sun drying, because it is more subject to control and gives superior products. Artificial dehydration is also used for other fruits, vegetables, eggs, milk, and meat. It can be accelerated and carried on at lower temperatures by the use of a vacuum.

Electronic dehydration is in the experimental stage. It promises to be particularly useful to reduce the water content to a very low level after a portion has been removed by other means. The products retain natural color and flavor to a high degree and reconstitute readily.

Freeze drying employs the principle of sublimation, that is, the direct passage of a substance from solid to vapor form. The food is first frozen and then dried under a vacuum, or self-freezing is brought about by exposure to a high vacuum which is prolonged to produce drying. As in electronic drying, the products retain superior palatability qualities, but, on account of high costs, it is as yet applied more often to medicinal products than to foods.

Predrying treatments include washing in the case of eggs, fruits, and vegetables, peeling in the case of certain fruits, and various forms of subdivision for meat and most fruits and vegetables. Meat may be cooked and ground before drying. Whole fruits such as prunes may be dipped in sodium carbonate or lye solutions to remove the wax and otherwise facilitate drying by producing small checks or cracks in the skins. Cut fruits and golden-bleached raisins are exposed to sulfur dioxide gas, and apples may be dipped in a solution of sodium bisulfite to preserve an attractive color. Vegetables generally require blanching to reduce drying time and to inactivate enzymes.

Preservation of dried foods can be prolonged by vaporproof packaging and by storage at low temperatures. A form of nonenzymatic browning, believed to result from condensation of amino acids and reducing sugars and known as the Maillard reaction, tends to develop in a variety of dried foods, including milk, eggs, and fruits. It is associated with deterioration in palatability and is difficult to control. In general, dehydration is an economical technic for preserving foods but less effective than freezing or canning in retaining desirable palatability qualities. It does not kill all pathogenic organisms, and, although dried foods are not suitable media for the development of bacteria, they may be agents for their transfer and thus for human infection, unless the foods are cooked before eating. Carotenes and ascorbic acid may undergo a high degree of inactivation.

Canning

Canning is a method of preserving foods which combines the technics of heating to kill spoilage microorganisms and inactivate enzymes with sealing in an air-tight container to prevent subsequent contamination. It is a suitable method for preserving any food which is acceptable in a moist-cooked form. Estimates place the number of commercially canned foods at over 400 kinds.

When canning was first invented, the emphasis was on developing practices which would ensure successful preservation. As this goal was achieved, attention was directed toward improving palatability, ensuring wholesomeness, and most recently toward conserving nutritive quality. The application of the findings of bacteriological, engineering, and nutrition research makes it possible to produce canned foods that are above the average in all these aspects on either a household or commercial scale.

The quality of canned foods depends upon (1) the characteristics of the original product or ingredients, (2) conditions of preliminary holding and treatment, (3) the processing technics, and (4) the conditions of holding before use.

The Characteristics of the Original Product or Ingredients

Canning itself never improves the nutritive quality of a food and seldom provides the ideal amount of cooking so far as palatability is concerned. Hence, in the canning of vegetables or fruits, starting with kinds and varieties that have high nutritive quality and retain desirable palatability qualities after the rigorous heating required for preservation are practices which help to ensure superior products.

Conditions of Preliminary Holding and Treatment

Many foods which are canned are highly perishable so that deterioration caused by bacteria or enzymes before processing must be guarded against. Fruits and vegetables should be harvested at the proper stage of maturity, cooled, and rushed to the can. Blanching of vegetables to inactivate enzymes as required for freezing is unnecessary for canning because the processing (heat treatment) performs this function. With leafy and other bulky products, however, it is required to reduce the bulk before packing in the can. Reusing the blanching water or using it to fill the can helps conserve soluble nutrients.

Fruits which darken on cut surfaces should be immersed in water, a salt solution, or the canning sirup, to preserve an attractive appearance and flavor. Adding ascorbic acid to the sirup or juice of some fruits serves the same purpose. Small amounts of calcium chloride may be added to tomatoes to increase their firmness during the overcooking required for their preservation.[5] On the other hand, the calcium and magnesium salts in naturally hard water may cause undesirable hardening in peas and beans and where it is possible should be replaced by natural or manufactured soft water.

Processing Technics in Canning

The most obvious difference among methods of canning is in the type of heat treatment, commonly known as processing. The principal types are open-kettle, water-bath, and steam-pressure processing. Oven processing which has occasionally been employed in the

[5] Kertesz, *New York State Sta. Circ.* 195 (1942).

household should not be practiced because jars may build up pressure sufficient to break the container and cause serious damage to surroundings.

Processing by Open Kettle. In open-kettle canning, the food is cooked and placed immediately in sterilized jars. Only acid products will keep when canned by this process. It cannot be used successfully with vegetables or meat, or with any food in tin cans, because the lids cannot be sterilized before sealing without damaging the composition or paper gasket which completes the seal. Consequently, it is employed primarily in household canning in glass and even there is being largely superseded by processing in the container because spoilage is comparatively less.

Processing by Water Bath. In water-bath processing, cans or jars containing the food are heated by submersion in boiling water. Removal of air from the container before sealing (exhaustion) is important because glass jars may break or "blow" their rubbers as a result of expansion of the air during heating, and because oxygen left in the container promotes oxidations which injure color and flavor and inactivate vitamins. The presence of oxygen permits the growth during storage of certain microorganisms which may withstand processing but would be prevented from development without oxygen. Finally, the removal of air produces a vacuum upon cooling which maintains an effective seal.

When food is packed hot [at least 170 degrees F. (77 degrees C.)], or heated in the unsealed container, the air is largely driven out. This should be accomplished before the cans are sealed. Except for the self-sealing type of glass jar, partial sealing of glass jars before processing with completion of the seal immediately afterward ensures the most complete exhaustion under household conditions.

Processing by Steam. Steaming is sometimes used for processing in home canning. Without pressure it gives the same temperature as a water bath. It is not recommended because it has no advantages which outweigh the disadvantages of the uneven heating caused by the difficulty of regulating heat to provide a constant supply of steam.

Processing by Steam under Pressure. The best method of processing nonacid products such as vegetables and meats is steam under pressure. All commercial canning of these foods is conducted in this way, and the process is duplicated in the household by the use of a pressure canner. When containers are filled with cold material, provision must be made for exhaustion as previously ex-

plained. The canner itself must also be "vented" (exhausted) before the petcock is closed to build up pressure. A mixture of air and steam under pressure gives temperatures that are lower than those corresponding to the same pressure produced by steam alone.

Sterilization need not be complete to ensure preservation of canned food, but successful canning procedure is directed to destruction of almost all living organisms within the can. Successful preservation also requires conditions which inhibit the growth of any surviving organisms and the prevention of entrance of outside microorganisms. The degree of sterilization is affected by (*a*) the temperature reached at the coldest point in the container during processing, (*b*) the length of the period of effective heating, (*c*) the hydrogen-ion concentration of the food being canned, (*d*) the kind of organisms and spores present, and (*e*) the kind of added ingredients which have antiseptic properties.

The temperature reached at the coldest point in the container during processing. A temperature of 212 degrees F. (100 degrees C.) kills microorganisms, but the spores of some bacteria can withstand this temperature for 6 hours or more in some types of food, and later start to develop and multiply. Steam processing, as it is carried on commercially in retorts under pressure giving temperatures as high as 488 degrees (270 degrees C.), or in the household by means of a pressure canner, will kill spores in a much shorter time.

Temperature distribution within a can depends upon its size and shape, its position—whether standing or lying on its side—the presence or absence of motion during the heating, and the consistency of the food and degree of fill. The consistency of the food is of particular importance because it affects the method of heat transfer. When there is enough liquid to permit convection currents, heating takes place more rapidly than when high viscosity or complete solidity restricts the method of transfer to conduction. When transfer is by conduction, the coolest point is the geometric center of the can, but when convection is present this point may be somewhat below the center.[6] Methods have been developed for measuring accurately the relation of these factors to the successful canning of particular foods.

The length of the period of effective heating. The period of effective heating is the period after microorganisms begin to be killed. At high temperatures much less time is required to produce the same sterilizing effect as is given by long periods at lower temperatures. Thus 3 minutes at 250 degrees F. (121 degrees C.) is as effective in killing spores of *Clostridium*

[6] Ball, *Food Technol.*, 3: 116 (1949).

botulinum as 360 minutes at 212 degrees F. (100 degrees C.). The commercial trend in canning is toward using high temperature-short time processing because it results in less damage to eating quality than longer heating at lower temperatures. When the period of heating is at an end, prompt cooling stops cooking, improves eating quality, and perhaps reduces nutritive losses.

Acidity of the material canned. Time-temperature combinations effective for killing microorganisms and spores are greatly influenced by the relative acidity of the pack.[7] For purposes of canning, foods are divided into "acid" types, those below *p*H 4.5, and "nonacid" types, those of *p*H 4.5 or above. Destruction of the spores of a spoilage organism occasionally found in tomatoes and other fruits, at 212 degrees F. (100 degrees C.) requires twice as long at *p*H 4.5 as at *p*H 4.1, and nearly five times as long as at *p*H 3.8.[8] Processing directions based on tests of keeping quality of typical samples of an acid food may be ineffective with occasional lots or individual cans, owing to natural variations in the *p*H of the fruit. For example, in one study the average *p*H of fancy sliced pineapple was 3.8, but the range was from 3.6 to 4.4, and cans taken from packs in which spoilage had occurred ran up to *p*H 4.7. Processing to 190 degrees F. (87.7 degrees C.) ensured keeping with *p*H of 4.4 to 4.5 or below, but a temperature above 200 degrees F. (93.3 degrees C.) was required to eliminate spoilage when the *p*H was 4.5 or above.[9] Such differences in acidity of the fruit probably account for some of the spoilage home canners find in acid fruits like tomatoes.

The above discussion has been concerned with the relation of acidity to destruction of nonpathogenic organisms in canning, but this factor is also extremely important in the killing of the dangerous *Clostridium botulinum*. In neutral solutions, spores of this organism may resist a temperature of 212 degrees F. (100 degrees C.) for 360 minutes. At 240 degrees F. (115.5 degrees C.), a period of 10 minutes is adequate for destruction.[10] To produce safe canned products from nonacid foods, water-bath processing is impracticable.

In general, *Botulinum* spores do not germinate in food having a *p*H of 4.5 or below. Hence all such foods may be safely processed in a water bath.[11] Tomatoes and other fruits come within this category. Unless strongly acid pickling solutions are used with nonacid foods, the pressure cooker should be employed for the improved safety it provides. There are on record, however, a few outbreaks of botulism from canned acid foods,

[7] Sognefest et al., *Food Res.*, 13: 400 (1948).

[8] Townsend, *Food Res.*, 4: 231 (1939).

[9] Spiegelberg, *Food Res.*, 5: 439 (1940).

[10] Tanner, *Am. J. Pub. Health*, 25: 301 (1935).

[11] Cameron and Esty, *Food Res.*, 5: 549 (1940). Townsend et al., *Food Res.*, 3: 323 (1938).

all but one home-canned.[12] Pears, apricots, and tomatoes were involved. The *p*H of these samples was not taken, but such records of hydrogen-ion concentration of all three fruits as are available do not range above *p*H 4.5. Undoubtedly, it is significant that all but one of these incidents was caused by home-canned food (the exception was a mixture in which the *p*H may have been high). Hence, even with the relatively safe acid fruits, reliable methods of home canning, such as those recommended by the BHNHE, should be followed meticulously, at least in all states where cases of botulism have been recorded.

The kind of organisms and spores present. The smaller the numbers of bacteria contaminating materials used for canning, the more successful the canning is likely to be. Cleanliness and freedom from disease and decay organisms are important for this reason. Important sources of contamination with spoilage organisms are the soil, the water, the equipment, decayed portions of the fruit itself, and added substances including sugar, which sometimes contains heat-resistant organisms.

The kind of added ingredients which have antiseptic properties. Sugars, salt, spices to an insignificant degree only,[13] and vinegar or other acids to a limited extent,[14] have antiseptic value when added to certain canned fruit and vegetables. Spices and vinegar are seldom used in amounts sufficient to preclude the necessity of using some form of processing with heat. Formerly, commercial canning compounds were used by homemakers to some extent, because they were believed to have antiseptic value. One such material (widely marketed a number of years ago) contained boric acid. It was found to have no value as a preservative, and it had deleterious effects on the health of experimental animals.

Sulfites have a preservative value when used with acid fruits but are not sufficiently reliable to be recommended for general use. In fact, there is no satisfactory chemical preservative.[15]

Canning with antibiotics, substances synthesized by one kind of bacteria which inhibit the growth of others, is in an experimental stage.[16] If they are shown to be practicable, they will have the advantage of greatly reducing the amount of heating required for preservation.

Conditions of Holding Canned Foods

Both the possibility of spoilage caused by the development of surviving organisms and the rate of deterioration in palatability and nutritive quality are affected by the storage temperatures used for

[12] Slocum et al., *Food Res.*, 6: 179 (1941).

[13] James, *U. S. Dept. Agr., Bull.* 98 (1932). Also Fabian et al., *Food Res.*, 4: 269 (1939).

[14] Erickson and Fabian, *Food Res.*, 7: 68 (1942).

[15] Council on Foods and Nutrition, *J. Am. Med. Assoc.*, 125: 355 (1944).

[16] Andersen and Michener, *Food Technol.*, 4: 188 (1950).

holding canned goods. Temperatures for long storage, in particular, should be below 50 degrees F. (10 degrees C.); the lower the better so long as freezing is avoided. Freezing itself does not cause spoilage but it may produce softened texture and break the seal of the container, thus permitting contamination which results in loss of the product.

Detailed directions for household canning can be obtained from state extension services or from the BHNHE. An excellent discussion of common problems is given by Esselen and Fellers in Massachusetts Agricultural Experiment Station Bulletin 461, "Causes and prevention of failures in home canning" (1950).

Use of Microorganisms

The use of microorganisms is a very old technic of preserving foods. It is essentially a chemical method because its effectiveness is a result of the production of substances such as organic acids by harmless organisms which retard the multiplication of spoilage types. The most common examples of preservation of this kind are ripened cheeses, fermented pickles, and kraut. Other vegetables which may be successfully fermented are beet tops, turnip tops, string beans, green tomatoes, beets, corn on the cob, lettuce, onions, cauliflower, peppers, and green peas. Clingstone peaches and Kieffer pears may also be processed in this way.

The most common type of preservation by means of microorganisms is the fermentation of self-contained sugars by lactic acid bacteria. The acid performs the function of depressing the development of other organisms which decompose proteins with consequent deterioration in edibility. Lactic acid bacteria are widely distributed in nature, being present in milk and on fruits and vegetables. They resist many environmental conditions unfavorable to other organisms and convert sugars to lactic acid without forming useless or undesirable products. For successful fermentation, the right strains of the bacteria must be present and provided with appropriate temperatures and concentrations of sugar and salt.

Another type of fermentation occurring in fruit juices is caused by yeasts and produces alcohol, but, unless inhibited, a sequence of other organisms converts the alcohol to acetic acid. In this way, vinegar is produced from apple juice.

In fact, all fermented foods tend to change as a result of a series of microbial actions. To stabilize a desirable stage it may be necessary to can or freeze the product.

Use of Chemicals

The use of chemicals for food preservation has declined with the advent and development of refrigeration, freezing, and canning. Salting still plays a role, primarily in connection with meats and fish, but the trend is toward reducing the concentration below the level at which it alone prevents spoilage, and to combine it with low-temperature storage. The principal exception to this development is the increasing use of chemical antioxidants, or packing in an atmosphere of nitrogen to prevent deterioration in fats or foods containing fat.

The relatively low status of chemical preservation is a result of the unavailability of substances which are effective in preventing spoilage and at the same time do not lower palatability and are demonstrably harmless to consumers. (See Chapter 3.) With the exception of salt, sugar, nitrates, vinegar, organic fruit acids, wood smoke, and alcohol, substances having a preservative action are critically and often unfavorably viewed by food officials because they may be used as substitutes for sanitary practices, conceal damage or inferiority, or possess harmful cumulative effects.

Other Less Important Technics

A major problem in the use of any of the previously described methods of preserving foods (except the use of antioxidants) is the more or less undesirable alteration in palatability qualities associated with the treatment. Canned foods seldom rival the original fresh product in color, flavor, or texture. Freezing may produce less change in color or flavor but be so destructive of texture as to be quite unsuited to the preservation of certain fruits and vegetables. Electromagnetic radiations of various wavelengths have been tested for their effectiveness in preserving foods without such shortcomings. Certain of these wavelengths show considerable promise of resulting in superior retention of original eating qualities along with the killing of spoilage organisms, with the result that they are being adapted to commercial use.

Sonic and ultrasonic radiations include electromagnetic wavelengths responsible for audible sounds and the next highest frequencies just out of the range of human capacity to experience them. When applied to foods, they have been found to reduce bacterial counts but to be impracticable for complete sterilization. They also tend to have the effect of mechanically subdividing agglomerated particles or delicate tissues with results that may or may not be desirable.[17]

Radio waves show promise for commercial use in the preservation of foods that require sterilization, pasteurization, the killing of insects, blanching, and dehydration. *Ultraviolet* radiations are in use for sterilization and for activation of provitamins D. Their germicidal action is employed to sanitize the air, utensils, and other equipment in the dairy products industry, and the surfaces of food in the meat and baking industries. Meat can be aged more quickly by holding it at warm temperatures than under refrigeration, and this is made possible by using ultraviolet radiation in the holding room to kill molds and bacteria in the air and on the surface of the meat. In the baking industry, ultraviolet radiations are useful to destroy the mold spores which might contaminate products before they are wrapped.

Other electromagnetic radiations, including X-rays, are being investigated with respect to their possible usefulness in food preservation on account of their germicidal action. Commercial applications are held back, however, by the necessity of eliminating the possibility of the hazard to health associated with radiations of these short frequencies.

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SECTION III

THE STRUCTURE OF FOODS

Introduction

The Significance of the Structure of Foods

Until the last half century the scientific study of food has been concerned mostly with determination of chemical compositions, or analyses, and the recognition of adulterants. These considerations are important, but they do not serve to explain the changes that take place during food preparation. When gelatin sets to form a gel, there has been no alteration in chemical composition, but the change in structure is exceedingly significant. The oil in mayonnaise may be stabilized by egg, gelatin, or cooked starch paste, all differing in composition, but serving the same purpose in the process of preparing this food.

Interpretation and control of most food-preparation processes depend upon an understanding of the physicochemical structure of foods and the effect of various agents upon it, as well as upon their chemical composition. Knowledge of both is essential if one would answer such questions commonly raised by the housewife as the following:

Why are some baking powder biscuits solid and hard instead of light and tender?

Why is one batch of fudge coarse grained and another fine grained, although exactly the same ingredients are used?

Why is some pie crust tough and hard?

What is the cause of "curdling" or "separating" in custards?

Why is a cut of meat tough when cooked by one method, but easy to cut or chew when cooked by another?

Why is fruit jelly sometimes sirupy rather than firm and quivering?

No attempt will be made to answer all these questions in this chapter, but the far-reaching effects that differences in ingredients and manipulation may have on structure will be suggested, exemplified, and, in a general way, explained. A "science" of food processing is still incomplete, but known facts of biochemistry and biophysics supply the answers to many questions of how and why.

CHAPTER 8

THE GENERAL STRUCTURE OF FOOD MATERIALS

Types of dispersions.

Various types of dispersions found in foods.

The dispersions medium, water, and its effect on the behavior of food materials.

Size of particles in a dispersion in relation to behavior of food materials.

True solutions and food preparation.

Colloidal dispersions and food preparation.

Suspensions and food preparation.

Factors which alter the degree of dispersion of components of foods.

Practically all foods have been living tissues or are products of living tissues. Even the eye can discern that they are not homogeneous structures, but that larger units are composed of smaller. When one looks at the outside of a potato, there is nothing to show that the whole mass is not brown, woody material like the skin. A view of the same potato in cross section reveals a very different condition: the outside skin is very thin, and the inside tissue white and watery. A closer examination shows further that the white tissue varies in different areas, that the layer directly underneath the skin is most dense, and that the tissue within the boundary is of two types: one, an inner, watery, branching core; and the other, which fills the space between the core and the surface layer, somewhat less watery. (See Fig. 3.) It is to be expected that these differences, which indicate unlike compositions and nutritive qualities, will result in unlike responses to cooking.

We have resolved the structure of the potato into its component parts only to the extent that this is possible with the naked eye. A microscope reveals further structural differentiation. It shows that all the differing areas are subdivided by cell walls, and that within these cells there are smaller bodies, some of which are spherical grains and are known by chemical analyses to be starch. (See Fig. 4.) We

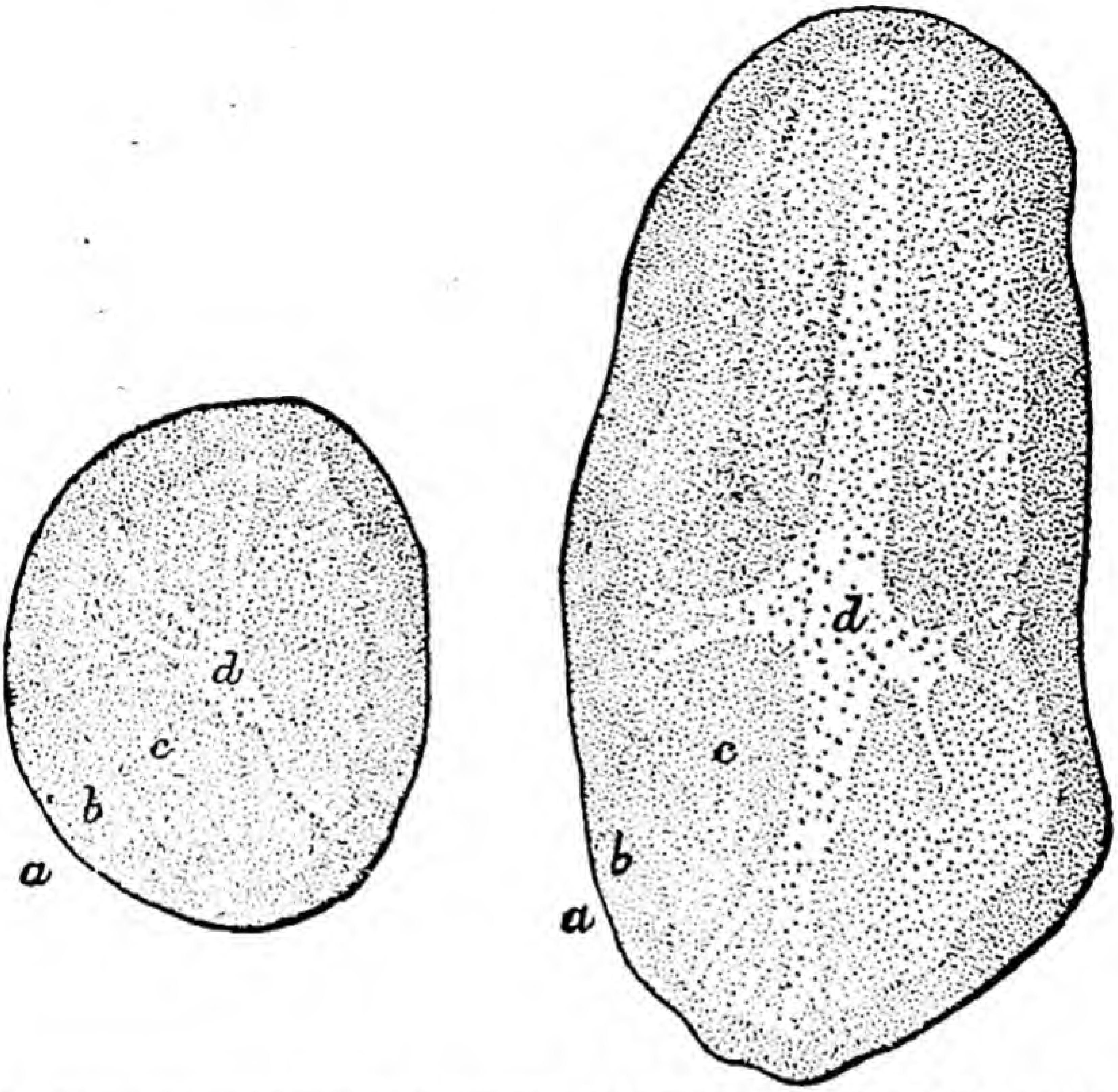

FIG. 3. Transverse and longitudinal sections of the potato as they look to the naked eye: (*a*) skin; (*b*) cortical layer; (*c*) outer medullary area; (*d*) inner medullary area. (*U. S. Dept. Agr. Bull.* 468.)

FIG. 4. Microscopic view of cross section of potato. (*U. S. Dept. Agr. Bull.* 468.)

have reason to believe that there are other smaller particles, so tiny that they are invisible even with the aid of our best microscopes. Another instrument, known as the ultramicroscope, is capable of showing where these particles are because of their property of scattering light, which makes them appear as bright dots in the field.

FIG. 5. Photomicrograph of the gold particles in a red-gold sol as viewed with an ultramicroscope. (*Courtesy R. A. Gortner.*)

(See Fig. 5.) In the potato, proteins are found among the components in this size category.

Smaller than the units made visible by means of the ultramicroscope are the molecules and ions and finally the electrons and protons which the chemist and physicist believe may be ultimate units of all ordinary matter. The starch grains, protein particles, and molecules and ions of the minerals are scattered through a medium, which, in the potato, is water.

Investigation has shown that the materials found in food respond to the processes used in their preparation according to the size and

state of their various structural units and the nature of the medium in which they are dispersed, as well as according to their chemical composition. In fact, it is on the basis of both factors that we shall be able to answer, if at all, many of the questions that a housewife asks about her food-preparation problems. For this reason, it is necessary to study the types of structural units in more detail.

TYPES OF DISPERSIONS

Materials subdivided into very small units and scattered through another substance are called dispersed materials. The combination of dispersed particles and the substance through which they are dispersed is called a *dispersion*. In foods, such particles are usually found dispersed in water. It is accepted terminology to call the particles in a dispersion the *dispersed phase*, and the substance through which they are scattered the *dispersions medium*. Thus, from this point of view, the potato is a dispersed system in which the dispersions medium is water, and the dispersed phases are the proteins, starch, cellulose, salts, fat, and small amounts of other components which the analytical chemist has found to be present.

There are two important ways in which dispersions may be classified. The first is based on the state of matter represented in each phase. Since there are three states of matter, it is possible to have dispersions in which the dispersions medium is a liquid, a solid, or a gas. In foods, as noted above, the dispersions medium is usually the liquid, water. The three states of matter likewise outline the possible types of dispersed phases as follows:

1. Dispersed phase a gas—foams, such as whipped egg whites (air in water).
2. Dispersed phase a solid—casein in milk.
3. Dispersed phase a liquid—emulsion, such as mayonnaise, in which the droplets of oil are dispersed in vinegar or lemon juice.

The second method by which dispersions may be classified is according to the size of the dispersed particles. All possible sizes have been subdivided into three approximately limited ranges because each of these is associated with certain peculiar properties. These three groups of dispersions are known as *true solutions, colloidal dispersions*, and *suspensions*. Some of the characteristics of each are here outlined.

True solutions	Colloidal solutions	Suspensions
Particles of dispersed phase are: Molecules or ions	Particles of dispersed phase are: Very large molecules or small groups of molecules called micelles	Particles of dispersed phase are: Larger groups of molecules
Less than 1 millimicron in diameter *	One millimicron to 0.1 micron in diameter	Greater than 0.1 micron in diameter
Invisible under any microscope	Visible under the ultramicroscope	Visible under microscope or to the eye unaided
Pass through filters and parchments	Pass through filters but not through parchments	Do not pass through filters
In molecular motion	In Brownian movement †	In gravitational movement

* One millimicron equals one-thousandth of a micron. One micron equals one-thousandth of a millimeter.

† To be defined later.

Transition systems exist between suspensions and colloidal dispersions on the one hand, and between colloidal dispersions and true solutions on the other. In other words, the sequence from true solutions to suspensions is continuous; the division made in the above classification is for practical working purposes. Any substance may be made to appear anywhere in the whole range by proper choice of conditions, including proper choice of dispersions medium.

VARIOUS TYPES OF DISPERSIONS FOUND IN FOODS

Under ordinary conditions, as they are found in food materials and as they function in the various preparation processes, the nutrients are dispersed in water as follows:

- Carbohydrates
  - Sugars—to form true solutions.
  - Starches—to form suspensions if the water is cold, colloidal dispersions when it is heated.
  - Cellulose—to form colloidal dispersions.
- Fats—to form suspensions and emulsions.
- Proteins—to form colloidal dispersions.
- Ash constituents—to form true solutions.
- Vitamins—to form true solutions, some in water and some in fat.

THE DISPERSIONS MEDIUM, WATER, AND ITS EFFECT ON THE BEHAVIOR OF FOOD MATERIALS

The heat capacity of water and steam and their responses to temperature changes have been discussed in Chapter 6. The rate and

amount of temperature changes have important effects on the changes in dispersions in foods during processing. Two other properties of water are of particular significance in food preparation: its capacity to dissolve other substances and its capacity to promote ionization of some of these substances.

Water surpasses all other liquids in its capacity to dissolve materials. For this reason, most natural waters contain considerable amounts of dissolved salts. Some of these give water the property known as hardness, of which there are two kinds, carbonate and noncarbonate (formerly called temporary and permanent). Hard waters form sticky curds with most soaps and prevent them from lathering quickly. Carbonate hardness is caused by calcium acid carbonate. When water that contains this salt is boiled, the salt decomposes to calcium carbonate, which precipitates to form the deposit of lime so frequently found in kettles, and carbon dioxide which is driven off. Noncarbonate hardness is caused by magnesium sulfate or calcium sulfate which cannot be removed from solution by boiling, hence the name "permanent," which was formerly used. The sulfates can be removed by chemical treatment, such as the addition of sodium carbonate or certain of the detergents now on the market. These change the calcium sulfate to compounds that have no important action with soap or in cleansing operations.

The capacity of water to promote ionization greatly increases the number of types of reactions that may take place in it. Ordinary chemical leavening agents like baking powder could not function in any other medium. Acidity and alkalinity are caused by hydrogen and hydroxyl ions released by substances in solution in water. Both are important in their effects during the processing of the biological materials used as foods. For this reason, it is necessary for the student to understand the methods by which they are measured.

The process of measuring total acidity or total alkalinity by titration to neutrality is familiar to anyone who has studied elementary chemistry. When an acid is titrated by a base, sufficient hydroxyl ions are added to combine with all the hydrogen ions that the acid can yield. Most acids or bases which are added to water in amounts above very dilute concentrations do not release all the hydrogen or hydroxyl ions that they have the capacity to release in extremely dilute solutions. Titration measures all the potential ions of either kind, because a compound is formed which takes them out of solution and permits dissociation to continue until the whole amount of the solute has been ionized.

In most biological processes or in the processing of foods, it is not the capacity of substances present to release hydrogen ions that is important, but the actual number of such ions active at any given moment.* This is spoken of as the hydrogen-ion concentration of the solution. The strength of an acid measured in terms of its total acidity is expressed by the volume of base of known normality required to titrate it, but a different method is used to designate differences in hydrogen-ion concentration.

Hydrogen-ion concentration is always measured in a water medium. Pure water is neutral, not because there are no hydrogen or hydroxyl ion present, but because both are released in equal amounts. The extent of the ionization of water is very small, calculations showing that 1 molecule in every 555,000,000 molecules is dissociated.[1] Another way of stating this is to say that water is 1/10,000,000th normal with respect to hydrogen and hydroxyl ions. It is customary to write such large figures exponentially, thus, 1×10^{-7}. This is further abbreviated to the expression *p*H 7, the negative exponent of the hydrogen-ion concentration being 7.

When a substance yielding hydrogen ions is added to water, the ionization of the water is repressed in such a way that hydroxyl-ion concentration decreases as the hydrogen-ion concentration increases. Consequently, an increase in hydrogen-ion concentration may be used to express a decrease in hydroxyl-ion concentration, so that one scale is employed for the measurement of both acidity and alkalinity. The converse situation, decrease of hydrogen-ion concentration as hydroxyl concentration increases, also occurs. With *p*H 7 as the neutral point, a scale from *p*H 1 to *p*H 14 covers a range of acidities from that of solutions 0.1 *N* in hydrogen ions to solutions which are 1.0 *N* base in hydroxyl ions and are still one hundred trillionth normal (10^{-14}) in hydrogen ions.

Expressing acidity in terms of hydrogen-ion concentration permits us to distinguish between strong and weak acids. Hydrochloric acid is a strong acid because it appears to be almost entirely ionized in a 0.1 *N* solution. Acetic acid releases hydrogen ions when it is in 0.1 *N* solution, but only to the extent that less than 1 per cent is ionized at any one time. It is a weak acid. If either acid in this

* Actually in aqueous systems, hydrogen ions probably do not exist independently but penetrate water molecules, forming hydronium, $(H_3O)^+$, ions.

[1] Gortner, *Outlines of Biochemistry*, Third Edition, John Wiley & Sons, New York, 1949, p. 67.

strength were titrated with 0.1 *N* sodium hydroxide, an equal volume of base would be required to neutralize it, but the strong acid would have much greater effects in certain biological processes. The *p*H of 0.1 *N* hydrochloric acid is 1.09, but that of 0.1 *N* acetic is 2.85.[2]

A *p*H value indicates an increase in acidity or hydrogen-ion concentration as it goes from 7 to 1, and an increase in alkalinity or hydroxyl-ion concentration in the range from 7 to 14. On the *p*H scale, *p*H 5 is ten times as acid as *p*H 6, *p*H 4 one hundred times as acid as *p*H 6, etc. *p*H determinations are made by using small amounts of dyes which give different colors responding to different hydrogen-ion concentrations, or by electrometric methods with an apparatus called a potentiometer.

Nearly all food materials contain substances such as certain salts or proteins which tend to repress changes in hydrogen-ion concentration. These substances are called buffers. When buffers are present, comparatively large amounts of acid or base must be added to change the *p*H.

Hydrogen-ion concentration is an important factor in the preparation of many foods. Examples include bread, cheese, jelly, and candy.

SIZE OF PARTICLES IN A DISPERSION IN RELATION TO BEHAVIOR OF FOOD MATERIALS

Ways in which the nature of water, whether added or present in the food material itself, conditions its role as a dispersions medium in foods have been suggested. We shall now turn our attention to a consideration of the effects of the size of the particles on the behavior of food materials.

True Solutions and Food Preparation

The confections and sirups such as honey and maple sirup which have sugar as a principal ingredient are good examples of true solutions. The principles of preparation of fondant are derived exclusively from the nature of sugar as a solute until transformed into a suspension.

[2] Gortner, *ibid.*, p. 70.

Concentration and True Solutions

The concentration of solute present in a true solution affects its properties greatly. The concentration possible varies with temperature and hence is altered during many food-preparation processes. Saturation, supersaturation, crystallization, and the formation of amorphous solids are all related to concentration and temperature. These subjects are discussed in elementary chemistry textbooks, to which the student should refer for review. Applications will be pointed out in later chapters.

General Properties of True Solutions

Of the general properties of substances in true solutions, two that enter into food processing in a significant way are (1) diffusibility and (2) effect on vapor pressure, boiling point, and freezing point.

Diffusibility of Substances in True Solutions. When a membrane permeable to solutes is placed between a solution and a pure solvent, the solutes will diffuse, that is move through the membrane into the pure solvent just as they would if no membrane were present. Diffusion may be employed to separate solutes from colloidal dispersions or suspensions if a membrane is placed between the solutions and a pure solvent. This process is called *dialysis*.

The cellulose walls of plant tissue and the coagulated proteins of meat act as membranes permeable to solutes during cooking. If foods of these types are cooked in water, there is a tendency for all substances in true solution—minerals, sugars, and water-soluble vitamins—to diffuse into the cooking water until the concentrations of these substances within the food and in the water are equal. On the other hand, the larger dispersed particles such as protein and starch, are held back by the cellulose or coagulated proteins and do not appear in the cooking liquids except as starch escapes from cut surfaces or *soluble* proteins diffuse.

When membranes are semipermeable, that is, are permeable to water but not to solutes, water moves through the membranes separating solutions of differing concentration until their densities are equalized. This process is known as *osmosis*. The force that would have to be exerted to prevent the passage of solvent molecules through the semipermeable membrane from the volume of pure solvent into the solution is known as the *osmotic pressure* of the solution. This pressure increases with the concentration of the solute

and depends upon the number of dissolved particles, not upon their individual properties. In an egg, the yolk contains a higher concentration of solutes than the white and is surrounded by the semipermeable yolk membrane. Hence, in the course of time, water passes from the white to the yolk, stretching and weakening this membrane.

Effect of Substances on Vapor Pressure and Boiling and Freezing Points. *The vapor pressure*, or tendency of a liquid to evaporate, is lowered by the presence of solutes. The amount of reduction is proportional to the molal concentration of solute. Because of this effect, bread dries out and cake gains moisture when they are kept together in a closed container. Bread, because it has a lower concentration of solutes, also has a higher vapor pressure than the cake and thus more of the water required to saturate the atmosphere in the container will evaporate from the bread. The cake with its high concentration of solutes not only loses water by evaporation more slowly, but absorbs extra moisture furnished by the bread.

Substances in true solution have pronounced effects on freezing and boiling points, lowering the former and raising the latter according to the number of particles (molecules and ions) of solute. (See Chapter 6.) One mole of a non-ionized and nonvolatile solute elevates the boiling point of the solution 0.94 degrees F. (0.52 degrees C.), and 1 mole of non-ionized solute lowers the freezing point 3.35 degrees F. (1.86 degrees C.). Thus sugar lowers the freezing point of ice cream and raises the boiling point of fudge. Salts, because their molecules ionize to form two or more individual particles each having the same effect as a molecule of sugar, exhibit greater effects at lesser molal concentrations.

Colloidal Dispersions and Food Preparation

The range of food-preparation processes that can be explained only by understanding the general behavior of colloidal dispersions includes such phenomena as the following:

- Swelling and softening in dried fruits, cereals, etc.
- Dough formation.
- Coagulation of egg on heating.
- Setting of gelatin.
- Clotting of milk by acid and rennin.
- Softening of connective tissue in meat.

Stabilization and Particle Growth in Colloidal Systems

We have seen that the colloidal state is intermediate between true solutions, in which the dissolved particles are molecules and ions kept in constant motion by their kinetic energy, and suspensions, which contain particles composed of large groups of molecules tending to settle out by gravity. When a precipitate is formed, it merely means that particle growth has passed beyond the colloidal stage. Thus a colloidal system may be considered the product of an incomplete precipitation, or, conversely, the product of an incomplete solution, when material in a mass is added to a dispersions medium, and disperses only to the extent that particles of colloidal size result.

Some substances, of which gelatin is an example, tend to reach the colloidal state in water and remain there indefinitely. Many colloidal systems are precipitated or dissolved with great difficulty and only under specially arranged conditions. As a group, however, they are considered a dynamic form of matter, tending to become true solutions or suspensions as the result of rather slight environmental changes. This tendency is evident when cream of tomato soup "curdles," or when custards "separate," and in connection with many other circumstances disconcerting to the cook.

Instability and many other properties of the colloidal state are caused by the comparatively large amount of the surface area of the dispersed phase. A square centimeter cube divided until it forms colloidal micelles possesses the tremendous surface of 6,000,000 square centimeters. All surfaces possess surface energy. This is caused by the special attraction similar molecules have for each other. Because those at a surface are not completely surrounded by similar molecules, they are more tightly drawn to the rest of their kind. This results in a higher concentration of molecules in the surface layers causing what is known as *surface tension*. The term *surface tension* is applied to the tension where liquid and vapor meet. The tension existing where liquids meet or a solid meets a liquid is called *interfacial tension*.

The amount of surface energy increases as the surface area is enlarged. Total surface energy is the product of surface area and surface tension, the latter being a property which varies with the nature of the material. According to physical law, energy of this type always tends to decrease. This may take place in two general ways: by decrease in the surface area, or by decrease in the surface tension. Decrease in surface area results when particles coalesce,

which explains why some colloids precipitate. Examples of changes in foods which produce decreased surface energy as a result of decreased surface area are growth of large crystals of sugar at the expense of small crystals in candy, or large crystals of ice at the expense of small in ice cream or frozen meat. Surface tension decreases when the temperature rises, when the micelles dissolve with the formation of a true solution, or when other substances are present which concentrate on the surfaces of the micelles. This last phenomenon is called *adsorption*, and will be discussed later. When surface tension is decreased by the presence of adsorbed substances, the stability of a colloidal system is increased. Thus, when conditions are such that the particles of the dispersed phase in any colloidal dispersion can aggregate, the tendency is for the growth of large units to continue at the expense of the small, until they reach such a size that gravity removes them from the dispersed state entirely.

Particles of colloidal size have lost kinetic energy, but they continue to move in all directions and to resist settling out by gravity. This is caused by a type of motion known as *Brownian movement*. Brownian movement is the result of the bombardment of the colloidal particles by the molecules of the dispersions medium. Chance makes these attacks so unbalanced, at any particular instant, that the particle will be moved for a short distance until the energy from another group of molecules shunts it off in another direction. Brownian movement is easily seen among the particles of the protein casein in milk when it is examined with the ultramicroscope. Most particles in the realm of suspensions are too heavy to be moved by this means, however.

Although the existence of Brownian movement explains why colloidal particles resist the downward pull of gravity, it does not explain why they do not hit each other, coalesce, and thus grow until gravity causes them to settle out of the dispersions medium. There are two factors which cause resistance to the natural tendency of colloidal micelles to grow and which thus promote stability of that state of matter. These are (1) the electrical charge which the micelles bear, and (2) the attraction that the micelles of some colloidal systems have for the dispersions medium, water, an attraction almost as great as that which the individual micelles have for each other. (See Fig. 6.)

The Electrical Charge of Colloidal Particles and Their Stability. By various means which it is not necessary to discuss here,

colloidal particles secure electric charges. In any one colloidal dispersion these are all of the same sign; that is, all of the particles are either positively or negatively charged. When Brownian movement causes two colloidal particles to approach each other, they are prevented from uniting by repulsion caused by the similar charges.

The stability contributed by the electrical condition of micelles may be very readily disturbed by the addition of very small amounts of electrolytes, some ions of which bear charges capable of counterbalancing the charges on the micelles. This permits aggregation to continue until it ends in precipitation. A typical example of this

FIG. 6. Diagram to illustrate the methods of stabilization of colloidal particles: (*a*) colloidal particle stabilized by the electric charge alone; (*b*) colloidal particle stabilized by a water shell; (*c*) colloidal particle stabilized by both an electric charge and a water shell.

is the curdling of tomato soup already referred to. The curds are clumps of casein particles. Their stability as a colloidal dispersion was destroyed by the ions released from the acid of the tomatoes.

Mutual Attraction of Colloidal Particles and Dispersions Medium. When the two phases of a colloidal dispersion are more or less soluble in each other, the system is termed *lyophilic*, or *hydrophilic* if water is the dispersions medium. When the dispersed phase (often called the discontinuous phase) is not at all soluble in the dispersions medium (continuous phase), the colloid is described as *lyophobic*. The term *hydrophobic* is used when the dispersions medium is water. In hydrophilic colloids, the particles are surrounded by a rather thick and tightly held shell of water, which tends to prevent coalescence and gives great stability to the system. Hydrophobic colloidal dispersions are stabilized principally by the electric charges on the particles and are especially sensitive to the addition of electrolytes. They are therefore much less stable than similar dispersions of the hydrophilic type. (See Fig. 6.) But it is very difficult to precipitate a hydrophilic colloidal dispersion like gelatin. Hydrophobic colloidal dispersions may be stabilized by the

addition of a small amount of hydrophilic type which coats the micelles and confers upon them hydrophilic properties. When a hydrophilic colloid serves this function, it is known as a protective colloid. This property is employed in some food-preparation processes. When white sauce rather than milk alone is used in making tomato soup, curdling is less likely to occur because the cooked starch paste and protein in the flour help protect the casein particles. In mayonnaise, though the particles of oil are so large that the dispersion is an emulsion, the type of suspension in which the two phases are mutually insoluble liquids, they are protected by the egg which contains hydrophilic colloids, and the dispersion is comparatively stable and permanent.

Sols and Gels

Within the colloidal realm itself, various degrees of aggregation or precipitation exist. Colloidal dispersions that pour are known as *sols;* those which do not pour but are jellylike and resemble solids are called *gels*. Gels may be regarded as partially precipitated sols in which there is no change in chemical composition or in proportions of the two component phases. A gelatin sol containing 98 per cent water will set into a stiff gel if given time and the right temperature conditions.

When gel formation occurs, the two phases apparently take on a different relationship. The dispersed phase becomes associated into a threadlike or "brushheap" formation that holds the liquid phase within its meshes. (See Figs. 7 and 8.) The threads themselves are believed to consist of micelles of the dispersed phase attached end to end so that they appear much like strings of beads. It is thought that at widely separated points along the brushheap threads, a particle of one thread is more strongly attracted to a particle of an adjacent thread than to water or becomes attached to it by a hydrogen bridge. In this way a spongelike structure is formed with intervening micelles which are so strongly attracted to water that they hold it within the meshes of the structural network. Another way of describing a gel is to call it a dispersion in which there are two continuous phases.

In some gels, the intermittent attractions responsible for the formation of the structure are disturbed by increased kinetic energy so that heating reverses them to the sol state. Gelatin and fruit jellies may be thus reversed to sols and reset to gels by means of appropriate temperature changes. On the other hand, such gels as

custard and sour milk clabber are not reversible under the influence of temperature changes.

As stated previously, newly set gels tend to be characterized by retention of all of the dispersions medium. Sometimes a condition may arise in which the brushheap particles become less hydrophilic and some liquid separates. Gelatin, agar-agar, and fruit jellies exhibit this phenomenon after more or less long periods of standing. It is known variously as bleeding, weeping, or sweating of gels, or more technically as *syneresis*. The liquid is not pure dispersions

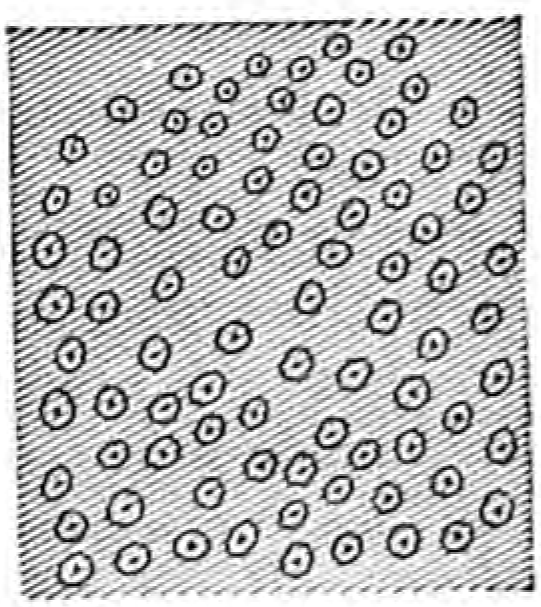

FIG. 7. Diagram of a hydrophilic colloid in the sol state showing theoretical structure.

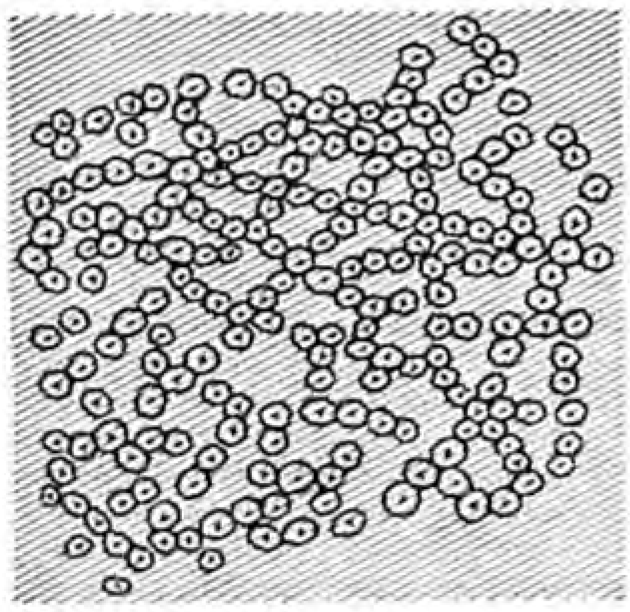

FIG. 8. Diagram of a hydrophilic colloid in the gel state showing theoretical structure.

medium but a sol containing some of each of the components of the system.

Some gels, especially after they have been dried, exhibit a tendency opposite to that of syneresis and become able to bind more water while still retaining the gel texture. When such gels as gelatin, gluten, and agar-agar are immersed in water, they may take on more water so that the mass swells considerably. This process is known as *imbibition*. It is also characteristic of dried fruits, vegetables, and cereals, when they are soaked in water.

Some sols, when partially precipitated, do not retain all of the dispersions medium but show a visible separation between the precipitate and supernatant liquid. These are known as flocculent precipitates, and the process is known as flocculation, as differentiated from gelation. The protein lactalbumin in heated milk forms a flocculent precipitate which coats the bottom of the pan. On the other hand, the casein sol of milk forms a true gel retaining all of the liquid when a sufficient degree of acidity is developed.

Properties of Colloidal Dispersions Important in Food Preparation

It is impossible to discuss all the many interesting properties of colloidal dispersions in this book, but a few have such important relationships to food-preparation processes that they will be referred to frequently. These include (1) adsorption, (2) viscosity, (3) diffusibility, and (4) effect on freezing and boiling points.

Adsorption. All solids tend to condense upon their surfaces a layer of any gas, liquid, or other solid with which they may be in contact and which diminishes the surface tension. This property is known as adsorption, as stated previously. The increase in surface represented by the colloidal state greatly magnifies the tendency of the material to hold or collect other substances.

Adsorption, or the accumulation of substances on surfaces, is to be contrasted with absorption, which refers to the accumulation of one substance within the particles of another. If a sol is precipitated, substances present in solution in the dispersed phase may be carried down with the precipitate by adsorption. Thus soup stock that is too salty may be rendered edible by addition of egg white, the cooked white (a protein gel) gathering and holding the salt on the surface of its particles. It is adsorption that causes protective colloids to be retained on the surface of the particles which they protect.

Viscosity. Viscosity is resistance to pouring. It is caused by friction between the particles in a liquid, whether those be molecules, colloidal particles, or material in suspension. When a substance requires special force to make it start to pour, it is called *plastic.* Solid fats and some starch pastes are plastic. In true solutions, viscosity depends upon two variables: the concentration of solute and temperature. In colloidal dispersions, it is influenced by such additional factors as hydrophilic quality, time and amount of agitation, degree of dispersion, and the presence of electrolytes or nonelectrolytes.

Hydrophobic dispersions have such a low proportion of dispersed phase that they are usually only slightly more viscous than the dispersions medium itself. Hydrophilic dispersions, on the other hand, may be very much more viscous than the dispersions medium, because the particles have an affinity for water and adsorb large amounts of it. This has the effect of enlarging the particles themselves because it is held so firmly. As a result, there is a great in-

crease in friction between the units of the dispersed phase, thus causing increased viscosity, or in converse terminology, decreased fluidity.

In cooking, the proportions of hydrophilic colloids are often varied to bring about changes in viscosity. The proportion of flour in a gravy or white sauce, or the proportion of gelatin in a salad mixture, is chosen in accordance with this consideration. A gelatin salad containing many pieces of fruit or meat which is to be molded into small individual units must be made from a firmer gel than a plain jelly in a large mold. To make the former type, one has merely to add more gelatin to the foundation jelly.

Viscosity and the rate at which it changes during heating are important in relation to heat transfer in many foods. In general, the greater the viscosity, the slower is the rate of heating because convection currents are reduced. This is particularly important in affecting the amount of time required to process such canned products as squash or pumpkin, for example.

Diffusibility of Colloidal Particles. Unlike substances in true solution, colloidal micelles cannot pass through animal membranes such as parchment, or penetrate other gel structures such as gelatin or a cellulose wall. This difference in behavior is probably a result of the difference in the relative sizes of the particles, those of colloidal size being too large to slip through the meshes of a gel. The relationship of diffusibility to losses by solution in the cooking of vegetables has been noted.

The Effect of Colloidal Particles on Freezing and Boiling Points. The pronounced effect that substances in solution have in raising boiling points and lowering freezing points has been discussed. In that connection it was pointed out that the actual amount of change was proportional to the number of dissolved particles. On account of their comparatively large size, there are relatively so few particles in colloidal dispersions that they do not noticeably affect freezing or boiling points. Thus the proteins in an ice cream mix do not affect its freezing point perceptibly.

Suspensions and Food Preparation

Among foods, there are examples of suspensions in which bubbles of air, droplets of liquid, and particles of solid, all consisting of relatively large groups of molecules, are the dispersed phase in a dispersions medium of water. In beaten mixtures like egg white or

whipped cream, suspended air bubbles are one of the components of a complex system containing other materials dispersed in other ways. When a suspension consists of one liquid dispersed in another, it is called an emulsion. Thus, according to the size of the particles of the dispersed phase, emulsions may be either colloidal dispersions or suspensions. Milk, mayonnaise, French dressing, and gravies are emulsions in which the particles are mostly in the suspension state. Starch mixed with cold water, and at least in some cases when heated, is a suspension in which the dispersed phase is a solid.

The Stabilization of Suspensions

Dispersion to form suspensions is usually produced by some sort of agitation. When the agitation is terminated, the particles tend to settle out by gravity if they are heavier than the dispersions medium, or to rise to the top if they are lighter. Cornstarch may be mixed with cold water to make a uniform dispersion, but, if the mixture is allowed to stand quietly, the cornstarch will gradually settle to the bottom, leaving a clear, supernatant layer of water. Emulsions, however, are commonly stabilized by the addition of a third material, usually a colloidal substance, which is called a *stabilizer* or *emulsifier*. This coats the droplets of one of the phases and confers the stability on the system that characterizes hydrophilic colloids. Pure liquids do not form foams. The air incorporated by beating escapes as soon as the agitation stops. But when a colloidal dispersion, especially one of the hydrophilic type, is whipped, the colloidal material is adsorbed on the surface of the gas bubbles in the form of a film which acts as a stabilizer.

When oil and water are the two phases of an emulsion, it is possible to have two types of emulsions, one in which the dispersed phase is oil, or another in which it is the water. (See Fig. 9.) The type produced is determined by the nature of the stabilizer. When the stabilizer possesses hydrophilic properties, the emulsion is of the oil-in-water type. A stabilizer which is insoluble in water and soluble in oil forms a water-in-oil emulsion. Both water-in-oil and oil-in-water emulsions are found among our foods. Milk proteins contribute some stability to the fat emulsified in the milk serum. Egg yolk serves as the emulsifier for the oil in mayonnaise. A small amount of gelatin and certain vegetable gums or finely divided solids more easily wetted by water than oil such as mustard

also emulsify oil in water. Butter and oleomargarine are probably examples of water-in-fat emulsions.

The stability of emulsions may be increased by decreasing the size of the dispersed globules. This is frequently brought about in milk and salad dressings by the process called homogenization, in which the droplets of fat are broken up by using tremendous pressure to force the product through small apertures.

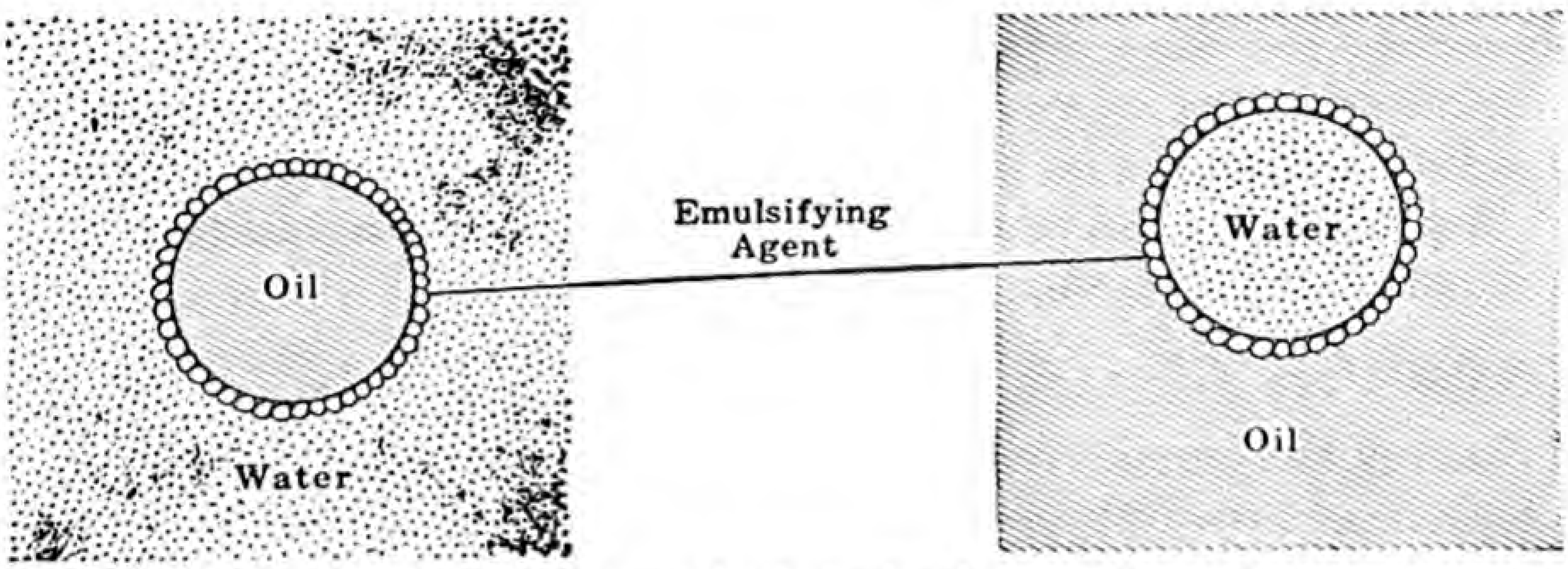

FIG. 9. Diagram showing the structural relationship between dispersed phase, dispersions medium, and emulsifying agent in an oil-in-water emulsion and in a water-in-oil emulsion.

A number of agencies, such as heat, cold, and acid, cause the "breaking" of an emulsion, that is, they produce a condition in which the droplets of the dispersed phase coalesce. This leads to a separation of the two phases.

Foams of importance in food preparation include those made from egg white, cream, and gelatin. In all three types, the dispersed bubbles are stabilized by protein films. Prolonged beating subdivides large bubbles producing more smaller ones. In egg white and milk, the protein in the films may be partially coagulated, increasing the rigidity of the foam. Cream foams are also stiffened and stabilized by the clumping of the fat globules in the protein films.

Properties of Suspensions

Emulsions share in many of the properties of colloidal dispersions, being nondiffusible through gels, having no appreciable effects on boiling and freezing points of the medium, and varying in viscosity. In all suspensions, viscosity increases with the number and size of

the dispersed particles. Emulsions may be prepared which are almost rigid because they have a very high proportion of dispersed phase.

Factors Which Alter the Degree of Dispersion of Components of Foods

In food processing some of the changes produced result from alterations in the degree of dispersion of certain components. The alterations may be condensation and crystallization in the direction of larger particles, or peptization * and solution in the direction of smaller particles. The most important factors altering the degree of dispersion in food processing are (1) temperature changes, (2) mechanical changes, and (3) chemical changes.

Temperature Changes

Raising the temperature of solutions in contact with crystals usually increases the dispersion of the crystals by promoting their solution. Raising the temperature of a gelatin gel disperses the "brush-heap" structure when it liquefies. But heating egg white decreases the dispersion of the egg proteins when they coagulate.

Mechanical Changes

Grinding, homogenization, and beating produce physical changes which may alter the degree of dispersion of food components. Grinding is used to increase the dispersion of flour. Homogenization, previously mentioned, increases the dispersion of fat in cream. Beating egg white decreases the dispersion of the protein by partially coagulating it. Churning cream decreases the degree of dispersion of the fat by causing clumping and some coalescence of the fat globules. Agitation of mayonnaise during transportation may also "break the emulsion," resulting in coalescence of the oil droplets.

Chemical Changes

Adding acids, bases, and other electrolytes, and the action of enzymes represent chemical factors which may alter the degree of dispersion in food components. Acids and bases in particular act by changing the charge on micelles. The behavior of proteins in colloidal dispersions is markedly affected by hydrogen-ion concen-

* Peptization is a term which is here applied to the reduction in size of any particles consisting of more than one molecule.

tration because they are amphoteric; that is, like acids they may donate protons or like bases they may accept protons. They are only weakly reactive, however, and dissociate as acids at low hydrogen-ion concentrations or as bases only when hydroxyl-ion activity is sufficiently low. At a particular intermediate *p*H value at which negative and positive charges balance each other, the micelles behave neither like acids nor like bases—will not migrate towards either a positive or negative electrode. This state of balanced charges is known as the *isoelectric point* and is usually designated as the particular hydrogen-ion concentration at which it occurs.

At the isoelectric point, proteins tend to respond either to a minimum or a maximum degree to factors which affect them. The swelling of gelatin is at a minimum at its isoelectric point. The casein of milk flocculates at this point producing a curd. This takes place during souring, the acid producing hydrogen ions which neutralize the original charge on the casein particles.

Outside the isoelectric point, changes in the charges on the micelles produced by variations in hydrogen-ion concentration also change the behavior of the micelles. Thus as the acidity of bread dough increases during fermentation, the gluten becomes softer, and in time, less elastic.

Added salts may change dispersions by reducing the hydration of the particles as well as by altering their electrical charge. Enzymes change colloidal dispersions sometimes by affecting the charge and sometimes by altering their chemical composition. The positively charged particles of rennin coagulate milk by neutralizing the negative charges on calcium caseinate. This, of course, is an example of decreased dispersion. On the other hand, a proteolytic enzyme in flour increases the dispersion of gluten during its action after water is added.

In discussing in later chapters the effects of various processes used in preparing individual foods, we shall find many other examples of the relation of internal structure to the qualities that we seek.

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SECTION IV

THE SELECTION AND PREPARATION OF FOODS

Introduction

Classification of Foods according to Their Nutritional and Culinary Roles

We have noted the classification of foods by the BHNHE in the Master Food Plans in Chapter 1. All important foods are placed in eleven groups, five of which are fruits and vegetables. In this section, where the emphasis is placed on principles and methods of preparation as well as appraisal of the products, it has seemed logical to treat all fruits and vegetables in the same chapter. Hence this section will be reduced to the following:

Chapter 9. Fruits and Vegetables.
Chapter 10. Milk and Its Products.
Chapter 11. Eggs.
Chapter 12. Meat and Allied Foods.
Chapter 13. Fats and Oils.
Chapter 14. Sugars and Food Mixtures High in Sugar.
Chapter 15. Grains and Their Products.

CHAPTER 9

FRUITS AND VEGETABLES

Since about 1920, the people of the United States have consumed increasing amounts of fruits and vegetables annually. (See Table XVI.) Per capita consumption of these foods cannot be calculated accurately because home production, which forms a considerable proportion of the whole, is variable and impossible to measure. But it is estimated that, with the exception of potatoes, all the major groups as we classify them have enjoyed expanding popularity, with citrus fruits far in the lead.

Table XVI. Approximate consumption of fruits and vegetables per capita, retail-weight equivalent in pounds by major groups, 1918–1948

[From *U. S. Dept. Agr., Misc. Pub.* 691 (1949)]

	Retail-weight equivalent in pounds			
Major groups	1918	1928	1938	1948
Leafy, green, and yellow vegetables	83	84	107	114
Citrus fruits and tomatoes	48	56	85	105
Potatoes and sweet potatoes	185	164	144	115
Dry beans, peas, nuts, soya products	12	14	17	16
Other fruits and vegetables	202	228	225	234

Popularization of modern nutritional science has increased general appreciation of fruits and vegetables and is partly responsible

for this trend. Furthermore, the diversity of climate in the United States coupled with an excellent transportation system has made it possible for all sections to have fresh as well as processed fruits and vegetables the year around. Nutritionists urge further increase in the use of these foods as a means of improving average health, and this, together with the appetite appeal of products of the constantly improving quality that our markets afford, is certain to continue the general upward trend.

THE STRUCTURE AND COMPOSITION OF FRUITS AND VEGETABLES

Like living tissues in general, fruits and vegetables have a cellular structure consisting of units of protoplasm, separated as in all plant tissues by walls of cellulose. When a plant cell divides during growth to form two daughter cells, there is secreted between them a layer of cementing substance called protopectin. Protopectin is a carbohydrate, and the layer that it forms is known as the *middle lamella*. Owing to the fact that the middle lamella is a double layer made of secretions of each boundary cell, there is a median plane of weakness where splitting occurs most readily.

Protopectin is also a component of the cell wall where it again functions as a cement, holding together the cellulose units (micelles). Hemicelluloses are likewise laid down in the cell walls, probably as reserve food materials. As will be pointed out later, changes in the protopectin produced by increasing maturity, or by the action of heat, affect the ease with which the cells separate and the resulting softening of the tissues.

Fruits soften as they mature because the protopectin changes to pectin, a more soluble substance. In a study of the changes in pectin in tomatoes during ripening, it was found that the pectin increased from 1.06 per cent in full-sized green fruits to 2.05 per cent in the red-ripe. At the same time protopectin decreased from 2.37 to 1.58 per cent.[1]

Until the tissue is killed by such processes as heating or freezing, the intact cellulose walls are semipermeable membranes. This means that, although fresh fruits and vegetables lose water by evaporation, substances dispersed in it are retained.

[1] Appleman and Conrad, *Md. Agr. Expt. Sta. Bull.* 291 (1927).

Besides water, making up 80 per cent or more of most fruits and vegetables, and the structural carbohydrates—cellulose and protopectin, mentioned above—all fruits and vegetables contain other carbohydrate—sugars or starch or both—protein, at least traces of fat, and a wide array of minerals and vitamins. Potatoes, dry beans and peas, corn, bananas, and nuts contain the highest proportion of carbohydrate. Nuts, dry beans, and dry peas outrank all other fruits and vegetables in protein. All fruits and vegetables are low in fat except avocados, olives, nuts, and soybeans. (See Table XVII.)

Vegetables such as peas and potatoes increase in starch content as they mature. Many fruits increase in sugar as they ripen. Those that contain starch, like bananas, may develop sweetness after harvesting because enzymes change the starch to sugar. But oranges, which contain no starch, cannot increase in sugar content after they are picked.

Besides sugar, other flavoring substances in fruits and vegetables include esters, aromatic compounds, acids, tannins, sulfur compounds, and unknowns. Tannins (phenolic acids or glucosides) are astringent (give a puckery mouth feel) and sometimes bitter to the taste. They are especially noticeable in chokecherries and persimmons, and diminish with ripening. Natural field ripening is necessary for the development of maximum flavor in peaches, strawberries, and melons, but not in pears or bananas.

The characteristic color of fruits or vegetables is a result of the presence of one or more distinct chemical compounds. Green is produced by *chlorophyll,* the reds and blues by *anthocyanins,* yellows and orange by *carotenoids,* and certain creamy whites by *flavones* and *flavonols.*

Chlorophyll is a complex organic compound composed of *chlorophyll a* and *chlorophyll b.* It is found in largest amounts in leafy vegetables but is also responsible for the color of green peas, green beans, broccoli, green asparagus, gooseberries, green grapes, and green plums.

Anthocyanins give color to red cabbage, red onions, beets, red and blue plums, red and purple grapes, red apples, blueberries, raspberries, strawberries, blackberries, etc. Many of this group act as indicators of the degree of acidity, tending to vary from red in very acid solutions to purple, blue, and even green in less acid or slightly alkaline solutions. In grape juice this property is responsible for the change in color produced by adding lemon juice, for example.

Table XVII. The proximate composition of typical fruits and vegetables *

(E.P., edible portions; otherwise analyses are as purchased)

Plant food	Water	Protein	Fat	Total carbohydrate	Ash
	Percentage				
Beets, E.P.	87.6	1.6	0.1	9.6	1.1
Carrots, E.P.	88.2	1.2	0.3	9.3	1.0
Onions, E.P.	87.6	1.0	0.2	10.6	0.6
Potatoes, E.P.	77.8	2.0	0.1	19.1	0.99
Turnips, E.P.	90.9	1.1	0.2	7.1	0.73
Asparagus	93.0	2.2	0.2	3.9	0.67
Celery	93.7	1.3	0.2	3.7	1.08
Cabbage	92.4	1.4	0.2	5.3	0.75
Lettuce	94.8	1.2	0.2	2.9	0.91
Spinach	92.7	2.3	0.3	3.2	1.53
String beans, E.P.	88.9	2.4	0.2	7.7	0.77
Green corn, E.P.	73.9	3.7	1.2	20.5	0.66
Green peas, E.P.	74.3	6.7	0.4	17.7	0.92
Squash, E.P., winter	88.6	1.5	0.3	8.8	0.83
Tomatoes	94.1	1.0	0.3	4.0	0.57
Dry beans	10.5	22.0	1.5	62.1	3.9
Dry peas, whole	11.6	23.8	1.4	60.2	3.0
Soybeans	7.5	34.9	18.1	34.8	4.7
Apples, E.P.	84.1	0.3	0.4	14.9	0.29
Avocados	65.4	1.7	26.4	5.1	1.4
Bananas, E.P.	74.8	1.2	0.2	23.0	0.84
Olives, green	75.2	1.5	13.5	4.0	5.8
Oranges, E.P.	87.2	0.9	0.2	11.2	0.47
Strawberries, E.P.	90.0	1.8	0.6	8.1	0.50
Almonds, E.P.	4.7	18.6	54.1	19.6	3.0
Chestnuts, E.P.	53.2	2.8	1.5	41.5	1.0
Peanuts, E.P., Virginia	2.6	26.9	44.2	23.6	2.7
Pecans, E.P.	3.0	9.4	73.0	13.0	1.6
Walnuts, black, E.P.	2.7	18.3	58.2	18.7	2.1

* *U. S. Dept. Agr., Circ.* 549 (1940).

The carotenoid pigments include the *carotenes*, *xanthophyll*, and *lycopene*. The first two are characteristically yellow or orange as in carrots, sweet potatoes, yellow corn, winter squash, peaches, and apricots; the last gives color to red tomatoes.

Flavones and flavonols are found in yellow onions and a few other fruits and vegetables. Often they are unnoticeable until soda which intensifies their yellowness is added, or cooking in an iron pan produces an unpleasant gray darkening.

Color is often a good index of maturity in fruits. The yellow, reds, and blues tend to increase as maturity advances, whereas chlorophyll decreases.

SELECTION AND USE OF FRESH FRUITS AND VEGETABLES

Appraisal of Fresh Fruits and Vegetables

Nutritive Quality in the Selection of Fresh Fruits and Vegetables

Because most fruits and vegetables are high in water and low in energy and protein values, they were, through the first decade of this century, considered luxuries to buy and of little value to eat. Proper appreciation of their importance could not develop until vitamins were discovered and their nutritional roles were understood. Now we know that, if we follow the general eating pattern of this country, we need to count on these foods for at least one-half of the *Recommended Allowance* of vitamin A and about nine-tenths of that of vitamin C.

Furthermore, the value of fruits and vegetables in contributing vitamins (other than A and C) and minerals should be more generally recognized. According to the 1948 survey of the BHNHE, these foods furnish about two-thirds of the vitamin A, over nine-tenths of the vitamin C, about one-third of the iron, about one-seventh of the calcium and riboflavin, and about one-fourth of the niacin and thiamine consumed. Many families failed to obtain enough of these nutrients, one-fifth running low in vitamin C and one-seventh low in vitamin A. More judicious selection of fruits and vegetables could increase vitamin A and vitamin C intakes, but probably few families would not benefit from consuming more of all types.

On the other hand, neither the value of fruits and vegetables nor any prejudice against meat as a food warrants the conclusion that a strictly vegetarian diet is desirable. It is impossible to plan true vegetarian menus that are adequate in calcium in particular, and vegetable proteins are so unbalanced in their amino acid content that they alone are not suitable for growing children. Most so-called "vegetarians" consume eggs and milk in addition to plant foods.

Because we are relatively so dependent upon fruits and vegetables for vitamins A and C, a classification of these foods based on their dietary roles should begin with the groups of most value for vitamins A and C. These groups are the leafy, green, and yellow types for vitamin A and citrus fruits and tomatoes for vitamin C.

Potatoes deserve a category of their own because they are eaten so frequently and in such relatively large quantities. In the south, sweet potatoes are more or less the mealtime counterpart of white potatoes in other areas, and, although the two differ considerably in nutritive quality, the BHNHE classifies them together. Dried beans, dried peas, and nuts belong together in a fourth group because they are especially important in supplying protein. All other fruits and vegetables are sufficiently alike in dietary significance to be classified in a fifth miscellaneous group. Thus, classifying fruits and vegetables according to their dietary significance gives:

1. Leafy, green, and yellow vegetables.
2. Citrus fruits and tomatoes.
3. Potatoes.
4. Dried beans, dried peas, and nuts.
5. Miscellaneous fruits and vegetables.

Group 4—dried beans, peas, and nuts—will be discussed in the section on Dried Fruits and Vegetables because the principles of preparing them are similar to those for artificially dried products.

In spite of the general nutritional basis for simplifying our study of fruits and vegetables by classifying them in the five groups mentioned, investigations have shown rather wide differences within each group. As already stated, vitamin A and vitamin C concern us most. Although analyses of different samples of the same kind of vegetable or fruit vary, we can learn which are generally the richest source. However, nutritive quality in fresh fruits and vegetables, those which have not been subjected to any form of processing after harvest except possibly holding, which will be discussed later, is af-

fected by such factors as the following: (1) kind of fruit or vegetable, (2) variety, (3) conditions of growth, (4) stage of maturity when harvested. Unfortunately, when we buy these foods we seldom have means of knowing the last three. In addition, household methods for preparing them to be served raw often adversely affect their nutritive value. Vitamin C is more subject to loss than other nutrients—it is fair to say that conservation of this vitamin means a high degree of conservation of all food value.

Losses of nutrients from fruits and vegetables are of two types, (1) losses by *solution* and (2) losses by *inactivation*.

Solution losses occur when liquids including juices and added water are discarded. Solution losses in fresh fruits and vegetables do not ordinarily occur before they are subjected to household preparation.

Inactivation losses result when a nutrient is so changed that it loses its value to the body. They appear to be caused primarily by oxidations and require oxygen plus enzymes or other catalysts such as particles of metals already in the food or acquired from a utensil. Holding at warm temperatures, especially if accompanied by wilting or crushing, causes losses by inactivation in many fruits and vegetables. Vitamin C is most readily affected, but vitamin A value is sometimes thus reduced before the food is subjected to any form of processing.

Fresh Fruits and Vegetables As Sources of Vitamin A. The vitamin A value of fruits and vegetables is dependent upon their content of the four provitamins *alpha, beta,* and *gamma carotene,* and *cryptoxanthin*. These are intensely orange pigments belonging to the carotenoid group, which the animal body can change to true vitamin A. Thus it is not strictly correct to speak of the vitamin A content of fruits and vegetables, though they may be said to have vitamin A value. Group 1 in the BHNHE classification, leafy, green, and yellow vegetables, will be broadened here to include the few fruits that contain comparatively large amounts of the provitamins A.

In green plant parts, the carotenoid pigments are masked by the chlorophyll. In general, the vitamin A value of plant materials increases with the intensity of their green, or, to a lesser extent, of their yellow color. Thus the green outer leaves of head lettuce have over thirty times the vitamin A value of the inner lightly colored

leaves. See Table XVIII for a list of the kinds of fruits and vegetables most potent in vitamin A value.

Table XVIII. Fruits and vegetables which have superior vitamin A value and furnish half or more of the *Recommended Allowance* of vitamin A per day for a physically active man in one serving. All other green and yellow vegetables have some vitamin A value but should not be relied upon exclusively unless liver is eaten at least twice a month

[Babcock, N. *J. Agr. Expt. Bull.* 751 (1950)]

Greens	Per cent of recommended allowance	Other fruits and vegetables	Per cent of recommended allowance
One-half cup cooked volume		Apricots—3 whole fresh or canned, a little more frozen or dried	50
Beet tops	108	Broccoli—½ cup cooked, a little more frozen or dried	50
Chard	45	Cantaloupe—½ cup diced of deeply colored	50
Collards	152	Carrots—½ cup cooked	181
Dandelion	273	Mango—1 medium	167
Endive, curly	50	Persimmon, Japanese—1 fruit	51
Escarole	50	Pumpkin—½ cup cooked	75
Kale	92	Squash, winter—½ cup, boiled, mashed	113
Mustard	100	Sweet potatoes—1 (5 x 2 in.) baked	228
Spinach	212		
Turnip	153		
Wild greens Analyses not available, but probably all leafy types qualify			

The range in vitamin A value of our various fruits and vegetables is very wide—from none at all in some to twice the *Recommended Allowance* (for an adult man) in ½-cup serving of cooked spinach.

Except for liver, the leafy-green vegetables are our most potent sources of vitamin A in terms of the amount furnished per serving. The number of kinds of leafy vegetables available for planting in the home garden, for purchase in the modern food market, or from the many edible wild plants offers opportunity for almost endless gastronomic adventures. As will be pointed out later, although many of the leafy foods are preferred cooked to raw, this does not affect vitamin A potency to an important extent. In fact, cooking greatly increases the value per serving because of the decrease in bulk that it produces. At least small proportions of most of the

leaves on the list give interesting variety when served raw in salads, however.

Although spinach heads the list almost everywhere in general availability and popularity, nutritionists urge more extended use of such greens of the cabbage family as kale, turnip and rutabaga tops, and collards. Besides being close rivals in vitamin A value (and outstanding in vitamin C), these cabbage-family leaves do not contain the oxalic acid present in spinach and other members of the Goosefoot family (beets, chard, and New Zealand spinach). During digestion, the oxalic acid combines with some of the calcium present, rendering it insoluble and hence unavailable for the body's use. This effect is of no significance in the nutrition of a person who consumes the recommended amounts of milk. Rhubarb leaves, however, contain so much oxalic acid that they are not safe to eat. The stems, of course, are quite wholesome because they contain much less.

Edible wild greens include milkweed, dandelion, fiddlehead (ostrich) ferns, winter cress, water cress, stinging nettle, dock, chicory, pokeweed, lamb's quarters, summer mustard, sorrel, purslane, and marsh marigold. Marsh marigold should not be eaten raw but parboiled to remove an unwholesome component.

Besides the wide range in vitamin A values among different kinds of fruits and vegetables there is great variability in potency among the varieties of a single kind. Some varieties of peas, for example, have three times as much carotene as others.[2] At Purdue University, by selecting tomatoes for carotene content, a strain having nine times that of the highest commercial variety was developed. Even more nutritious varieties may be bred and selected in the future.

Production factors, such as amounts and kind of fertilizer used and the stage of maturity at harvest, affect vitamin A value. Green beans are highest in potency in the immature stages and gradually decrease as they approach maturity.[3] In carrots, the carotenes increase up to the best marketing stage and then decrease somewhat.[4] On the other hand, tomatoes increase in vitamin A value as they ripen. Also field-ripened tomatoes are much higher in carotene content than those picked green and ripened in storage or grown in greenhouses. In the winter ripe tomatoes on northern markets

[2] Scott and Belkengren, *Food Res.*, 9: 371 (1944).

[3] Flynn et al., *J. Am. Dietet. Assoc.*, 22: 415 (1946).

[4] Pepkowitz et al., *Plant Physiol.*, 19: 615 (1944).

have on the average only one-third as much vitamin A value as summer vine-ripened ones.[5]

Methods used in preparing fruits and vegetables for serving in the raw form may alter nutritive value. Some factor, probably an oxidizing enzyme, greatly reduces the vitamin A potency of raw green leaves if they are chopped.[6] Paring and slicing peaches also produces some loss.

In preparing fresh fruits and vegetables we sometimes discard edible portions which have important food values. Analyses of a large number of edible leaves show that the blades contain several times as much carotene on a *dry* basis as the midribs and petioles (stems). This does not mean that the stems are not worth eating, but that, instead of letting any of these perishable foods go to waste, one might well conserve the most valuable portion.

Carotenes are not water-soluble and therefore only a small proportion of them appears in fresh vegetable juices expressed by means of a juice extractor.[7] This would not be true, of course, in tomatoes or other fruit products containing finely divided fruit pulp.

Fresh Fruits and Vegetables as Sources of Vitamin C. The BHNHE in its classification of fruits and vegetables according to general nutritional roles assigns one category to citrus fruits and tomatoes. Whether fresh or processed, these foods are our most reliable sources of vitamin C. Studies show that the ascorbic acid potency of typical diets is closely related to how much of them is eaten. However, a number of vegetables are significant sources if they are fresh and unwilted or lightly cooked without solution losses.

As stated previously, we are almost completely dependent upon fruits and vegetables for our vitamin C. Milk contains a small amount of this vitamin, but elsewhere it is absent from common foods. The best way to ensure an adequate intake is to consume one serving daily of a food containing at least half the *Recommended Allowance*. (See Table XIX.) The remainder will usually be provided by potatoes, and miscellaneous fruits and vegetables, and milk.

Vitamin C, like vitamin A, has a wide range of potency, not only among kinds of fruits and vegetables but also among varieties of the

[5] Holmes et al., *New England J. Med.*, 229: 461 (1943).

[6] Booher et al., *Food Res.*, 6: 493 (1941).

[7] Puffer et al., *Food Res.*, 7: 140 (1942).

Table XIX. Fruits and vegetables which are superior sources of vitamin C and furnish approximately one-half of the *Recommended Allowance* of vitamin C for a physically active man

[Babcock, *N. J. Agr. Expt. Sta. Bull.* 751 (1950)]

Fruits	Per cent of recommended allowance	Vegetables	Per cent of recommended allowance
Cantaloupe		Brussels sprouts	
Fresh—⅓ melon, 5 in. diameter	52	Cooked *—¾ cup	61
Grapefruit		Cabbage	
Fresh—½ small fruit	66½	Raw—¾ cup	50
Canned—½ cup	49½	Cooked—¾ cup	53
Grapefruit juice		Cauliflower	
Fresh—½ cup	66	Raw—½ cup flower buds	46
Canned (sweetened)—½ cup	58	Cooked—1 cup	45
Frozen concentrate—½ cup, reconstituted	61	Collards	
		Cooked—½ cup	58½
Honeydew melon		Kale	
Fresh—⅓ melon, 7 in. long	45½	Cooked—¾ cup	56
Mango		Kohlrabi	
Fresh—⅔ medium fruit	55	Cooked—¾ cup	57
Orange		Mustard greens	
Fresh—½ medium fruit	51	Cooked—¾ cup	63
Orange juice		Pepper (green)	
Fresh—½ cup	81½	Raw—½ medium	51
Canned (sweetened)—½ cup	70	Cooked—½ medium	43
Frozen concentrate—½ cup, reconstituted	63	Spinach	
		Cooked—¾ cup	54
Papaya		Sweet potato	
Fresh—½ cup diced	68	Boiled—1	54½
Strawberries		Tomato	
Fresh—½ cup	59½	Fresh—1 medium	46½
Frozen—3-oz. serving	47	Cooked—1 cup	53
Tangerine		Canned—1 cup	53
Fresh—1½ medium fruit	50	Tomato juice	
Tangerine juice		Canned—1 cup	51
Fresh—½ cup	50	Turnip greens	
Canned—¾ cup	64	Cooked—½ cup	58
		Water cress	
		Raw—2 oz.	58½

* In all instances where the product is cooked, light cooking in a small amount of water is assumed.

same kind. An average medium apple furnishes only about 8 per cent of the *Recommended Allowance* for an average man, but the New York Agricultural Experiment Station found, in testing 94 varieties, that some had twenty times as much ascorbic acid as others

and the highest rivaled citrus fruit.[8] As is true for vitamin A value, there is great opportunity for increasing the average vitamin C contributions of fruits and vegetables by developing new, more potent varieties.

Fertilization and other production practices also affect ascorbic acid values. Among the more important is exposure to sun. The side of an individual fruit receiving the greatest direct exposure has the highest potency; staked tomatoes have higher values than those on vines allowed to spread on the ground, probably for the same reason. Also smaller fruits tend to have higher potencies, again no doubt because their larger surface in relation to volume results in greater effect of the sun. The difference in light intensity probably explains why field-ripened tomatoes contain more ascorbic acid than greenhouse products.

The stage of maturity at harvest may also affect vitamin C potency. The effect varies from product to product—tomatoes and peaches increase in ascorbic acid content as they ripen, grapefruit and oranges decrease in relative potency but the total amount increases because the fruits are larger. Vine-ripened strawberries and tomatoes have a higher vitamin C content than those picked before they are ripe and then ripened off the vine.

Artificial ripening of fruit by exposure to proper concentrations of ethylene gas speeds up such changes as disappearance of green color, softening of texture and change of starch to sugar. It has no effect on vitamin content, however.

The ethylene process is often employed to remove green color fr. the skin of Valencia oranges, a variety which may have cor. .erable chlorophyll in the skin when internal ripening changes are complete. Consumers are assured a proper degree of ripeness in this fruit by a federal requirement that the appropriate acid-sugar ratio be reached before marketing. Dipping oranges in a solution of an oil-soluble aniline dye is another method of coloring them which is more rapid than the ethylene process and is, in some cases, more successful. The Food and Drug Administration has not been able to show that dyeing has any adverse effect on the health of consumers even when the dyed peel is eaten in marmalade. Such fruit must be labeled "color added." There has been some consumer opposition to artificial coloring, especially by dyeing, but it has not been sufficient, nor has the evidence of concealment of inferiority

[8] *New York Expt. Sta. Rept.* (1945), p. 25.

been conclusive enough, to overcome producer pressures in behalf of the procedure.

As is true of vitamin A value, ascorbic potency varies with the parts of the plant. In cauliflower and broccoli the vitamin is in larger proportion in the blossoms than in the stems.[9] In a study of twelve leafy vegetables it was found that the leaf blades were much richer than the stems.[10] But in contrast to provitamins A, ascorbic acid is water-soluble, and hence the freshly expressed juices of fruits and vegetables have potencies on the basis of weight approximating those of the original products. However, in nonacid products, juicing exposes vitamin C to air and inactivation may be rapid. Cabbage and spinach juice prepared with a vegetable juice extractor lose two-thirds or more of their vitamin C content in one-half hour of standing.[11] But the more highly acid fresh orange and tomato juices lose no appreciable amounts of vitamin C during the first 24 hours when they are held in covered containers in a refrigerator.[12] In fact, more recent (1945) tests of orange and grapefruit juices show that there is little change in potency, whether the juices are covered or uncovered, for as long as a week at refrigerator temperatures or for 3 days at room temperatures. Flavor, however, was better when the juices were covered and held in a refrigerator for not more than 3 days.[13]

Shredding and chopping, especially if accompanied by crushing, release enzymes and possibly metallic ions which cause fairly rapid inactivation of vitamin C. To be certain of maximum retention of this vitamin, cabbage or other vegetables should be sliced with a sharp knife or shredder rather than chopped. There is evidence that it may also be best to add salad dressing only a short time before serving.[14]

The Nutritive Contributions of Potatoes and Sweet Potatoes. In the quantity in which they are eaten, particularly by families who must keep food costs down, potatoes and sweet potatoes make substantial contributions to nutrition. (See Table XX.) Potatoes are relatively low in calcium and vitamin A value; sweet potatoes,

[9] Wheeler et al., *Food Res.*, 4: 593 (1939).

[10] Sheets et al., *Food Res.*, 6: 553 (1941).

[11] Booher et al., *Food Res.*, 6: 493 (1941).

[12] McElroy et al., *J. Home Econ.*, 31: 325 (1939).

[13] Moore et al., *J. Home Econ.*, 37: 290 (1945).

[14] Quinn et al., *Food Res.*, 11: 163 (1946); Clayton and Goos, *Food Res.*, 11: 163 (1946); Wilcox and Neilson, *J. Am. Dietet. Assoc.*, 23: 223 (1947).

Table XX. The nutritive value of potato and sweet potato, given as percentages of the *Recommended Allowances* for a physically active man

[Babcock, *N. J. Agr. Sta. Bull.* 751 (1950)]

Food, description and measure	Food nutrients: Energy	Protein	Calcium	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Ascorbic acid
Potato, 1 medium, baked,* 4½ oz. or 128 grams	3½	3½	1½	6½	½	7½	3	9½	22½
Sweet potato, 1 medium, baked,* 4¼ oz. or 120 grams	6	3½	4½	9	228	8	4½	6	37½

* The effects of other methods of cooking will be discussed later.

in protein, calcium, and riboflavin. Both provide extra amounts of vitamin C, and sweet potatoes are an excellent source of vitamin A. If it were not for the general use of one or the other of these foods, more severe and widespread signs of scurvy, especially in the late winter and early spring, would be common among our population.

In connection with potatoes, it should be pointed out that an average serving yields only 100 calories, or one-thirteenth of the *Recommended Allowance* for an average man. As compared with rich desserts, meats, and other fatty foods, this vegetable is not fattening. With a little milk for calcium, and butter or fortified margarine for vitamin A, the potato becomes a well-balanced food which might well be eaten in larger amounts when economy is sought.

The Nutritive Contributions of Miscellaneous Fruits and Vegetables. The miscellaneous fruits and vegetables omitted from the previous categories do not make outstanding contributions of any one nutrient. Green peas, green beans, green asparagus, yellow peaches, and yellow sweet corn are generally well-liked, and the double serving often eaten makes them worthwhile sources of vitamin A. All fresh fruits and vegetables contain ascorbic acid, some of which needs to be added to that provided by one serving from the potent list, given in Table XIX, and that from potatoes to meet the *Recommended Allowance* for the day. As previously stated, all fruits and vegetables contribute to our needs for most other nutrients—to some extent at least.

The outer green leaves of lettuce and cabbage have vitamin and mineral contents which are higher than those of the bleached interior. The nutritional values of celery leaves are superior to those of the stalks and might well be utilized by being eaten along with the stalks or in poultry stuffing, soup, or other cooked dishes.

Digestibility of Fresh Fruits and Vegetables

The completeness of digestion of unprocessed fruits and vegetables depends principally upon their cellulose content. Though some of the fiber of vegetables and fruits is changed enough to be absorbed during its passage through the digestive tract, most of this component remains to add to the fecal waste. The bulk furnished by the cellulose and water-holding pectins, together with certain acids and salts present in these foods, gives some of them high laxative value. Children and some adults may fail to digest such vegetables as raw carrots, because they chew too imperfectly to secure much disintegration, and possibly because their digestive systems have even less than average action on cell-wall constituents. Raw vegetables low in protein, such as carrots, lettuce, celery, cabbage, tomatoes, and cucumbers, leave the stomach rapidly and without much change. Hence such foods have little "staying-by" quality, but for this reason and, in the case of fruits, on account of their quickly absorbed carbohydrate, they make desirable between-meal lunches.

Sanitary Quality of Fresh Fruits and Vegetables

In this country, the danger from contamination of fruits and vegetables is less than in countries where the method of sewage disposal results in soil contamination. Nevertheless, many of our soils contain pathogenic organisms which may pollute plant materials that come in contact with them. Furthermore, we buy many of these products after they have been exposed to dust and insects and have been handled by numbers of people. In an examination of 29 samples of such vegetables as lettuce and celery, *Bacillus coli* was found on 22 of them. This is an organism the presence of which indicates contamination with human excreta.

Fresh fruit is also likely to be contaminated with bacteria of this type. In a comprehensive review of the subject, it is authoritatively pointed out that bacteria do not penetrate the interior of sound fruits and vegetables, that it is safer to prevent contamination than to rely

certain certain

on procedures in the kitchen to avoid infection, and that an appearance of cleanliness does not guarantee safety.

Thorough washing and removal of even slightly spoiled portions should be the minimum precautions taken. Children are more susceptible to alimentary infections than most adults. Special care, therefore, should be used in cleansing fruits and vegetables if they are to eat these products uncooked.

Palatability of Fresh Fruits and Vegetables

The palatability of fresh fruits and vegetables is judged by such qualities as appearance, including relative freedom from defects, flavor, odor, and texture. These qualities, like nutritive value, depend upon variety, environment during growth, stage of maturity when harvested, time and conditions of holding after harvest—all factors over which the consumer may have no direct control. On the wholesale market, transactions are made largely on the basis of voluntary grades which have been defined for fruits and vegetables of commercial importance. These grades were not developed for the use of consumers, and the grade designations seldom appear on the retail market units. However, the United States Department of Agriculture has begun to establish separate consumer grades, and they are now available on a voluntary basis for potatoes, spinach, tomatoes, celery, and carrots. A number of states have also developed consumer grades for certain fresh fruits and vegetables, some of which are compulsory. The problem of changes occurring after grading has taken place at the farm or wholesale market is a handicap to development of grading of perishable products at the retail level.

Under present conditions, personal selection of perishables at the market is likely to give the greatest satisfaction. The intelligent shopper will learn not to rely exclusively on eye appeal. Large size in fruits may be associated with inferior flavor and texture qualities. Certain types of skin defects in such fruits as apples and grapefruit, or dirt on potatoes have no relation to interior quality. Buyers should refrain from rough handling of fruits and vegetables at the store because this causes spoilage which is ultimately added to the selling price of these foods. When fruits and vegetables show decay, the portion which can be salvaged is not readily ascertainable, and inferior eating quality may extend to undamaged areas. Such products are not worth buying unless the price is low enough to justify the risk.

Perhaps the principal problem in retaining original palatability qualities of fresh fruits and vegetables is the darkening which develops on exposure to air of cut surfaces of some varieties of these foods in raw form. This change may develop also as a result of bruising or other damage. The darkening or browning effect is caused by oxidases, or other enzymes which act on substances containing the catechol group, such as certain of the tannins, the amino acid tyrosine, and perhaps other compounds. Raw potatoes, peaches, bananas, some varieties of apples, pears, apricots, etc., show this reaction.

Practical methods of preventing enzymatic browning are based on interference with the action of the enzymes either by preventing contact with oxygen or by direct inhibition. Water, weak brines, sugar solution, or acid solutions prevent contact with the air and are often effective, the acid solutions being especially effective because increasing the hydrogen-ion concentration decreases the rate of darkening. Fruit juices, such as those from fresh or canned citrus fruits or canned pineapple, are very satisfactory for this purpose and often have the advantage of making a desirable addition to the flavor of other fruits. Besides being acid, pineapple juice and probably the other fruit juices have a specific inhibiting action caused by sulfhydryl compounds which they contain. Another way of preventing contact with oxygen is to cover the cut surface with a reducing agent. Sulfur dioxide has long been used in this way commercially to prevent darkening of dried fruits, and ascorbic acid is now being used with fruits for freezing. Most of the added vitamin is inactivated by oxygen, but in addition to preserving fresh color the ascorbic acid retards deterioration in flavor.

Another kind of darkening sometimes occurs on cut surfaces of fresh fruits and vegetables containing tannins which have come in contact with iron in a knife or other utensil. This may be seen when red cabbage or lettuce is sliced.

Economy of Fresh Fruits and Vegetables

The factors of greatest importance in judging the relative economy of fresh fruits and vegetables at the market are (1) the market supply, (2) the relative nutritive contributions, especially of vitamins A and C, and (3) the proportion that is edible.

The Market Supply. Usually fruits and vegetables are cheapest when in season or for other reasons in large supply on the market. Following price changes is especially worthwhile with perishable products.

The Nutritive Contributions, Especially of Vitamins A and C. Foods that are relatively costly per serving may be relatively cheap as a source of a particular nutrient. Among common fresh vegetables those that are usually best buys for vitamin A value are carrots, spinach, broccoli, winter squash, beet greens, and sweet potatoes. Fresh fruits and vegetables that are usually the best buys for vitamin C include cabbage (red or green), rutabagas, grapefruit, oranges, peppers, and spinach.[15] Nutritive quality is not closely related to palatability qualities (or grade) of fresh fruits and vegetables so long as defects do not include wilting or spoilage.

The Proportion That Is Edible. The proportion of inedible waste is an important factor in the real cost of many fresh fruits and vegetables. It varies not only with the kind of product but also with variety, size, quality, and method of preparation. Raspberries, blackberries, and blueberries of high quality have no waste as they are marketed. Apricots, cherries, grapes, plums, strawberries, and onions have low waste, less than 10 per cent. On the other hand, more than half of the purchase weight of fresh Lima beans, green corn, green peas, watermelon, and canteloupe is inedible.

Waste in many cases depends a great deal upon household preparation practices. The proportion discarded in paring and trimming varies tremendously with quality and with the technics of the cook. Studies show that losses, expressed as percentages, with different products may vary as shown in the accompanying list.[16]

Asparagus	34–52	Cauliflower	62–78
Snapbeans	3–19	Head lettuce	23–50
Beets (without tops)	10–25	Potatoes	14–52
Broccoli	13–50	Spinach	22–49
Cabbage	11–39	Sweet potato	16–29
Carrots (without tops)	12–38	Turnips (without tops)	11–49

The BHNHE has estimated servings per pound of fresh vegetables and fruits as indicated in Table XXI.

Losses in oranges prepared by different methods are given in Table XXII. In this case, method was not as great a variable, however, as size.[17] Since small oranges are nearly always the cheapest and, as mentioned previously, highest in vitamin C potency, it is obvious that they are the best buy.

[15] Rollins, *Cornell Univ. Agr. Expt. Sta. Bull.* 845 (1948).

[16] Gordon et al., *J. Am. Dietet. Assoc.*, 25: 142 (1949).

[17] Browning and Pittman, *J. Home Econ.*, 21: 45 (1939).

Table XXI. Average servings per pound of fresh fruits and vegetables as purchased

[*BHNHE Misc. Pub.* 662 (1950)]

Food group	Servings per pound
Leafy, green, and yellow vegetables	
Beans, green	4
Broccoli	3
Carrots	3 to 4
Greens, salad, raw	8
Greens, cooked	2 to 3
Peas	2 to 3
Squash, winter	2 to 3
Citrus fruit, tomatoes	
Oranges or grapefruit, sections or juice	2 to 3
Tomatoes	3 to 4
Potatoes, sweet potatoes	3 to 4
Other vegetables and fruits	
Vegetables	3 to 4
Fruits	3 to 4

Table XXII. Average percentage of waste from small, medium, and large oranges when prepared by various household methods

(After Browning and Pittman)

Size of orange	Method of preparation						
	Halved		Juice	Sliced		Divided into sections	
	(1) *	(2) †		Pared	Peeled	(1) ‡	(2) §
Small (324)	40.21	43.81	53.20	45.96	31.42	31.35	52.35
Medium (200)	39.45	42.92	59.55	38.34	31.52	30.34	51.85
Large (80)	44.16	46.06	67.63	39.65	36.39	32.91	60.93

* Not cut around edge.
† Cut around edge.
‡ With membrane.
§ Without membrane.

Holding and Storing of Fresh Fruits and Vegetables

Fruits and vegetables are living tissues in which two types of processes continue simultaneously: one is the constructive building of new tissues and storing of reserve nutrients; the other, a destructive breaking down of carbohydrate in respiration. Both are promoted by self-contained enzymes. During rapid growth, the constructive synthetic processes overshadow the losses of respiration, but as maturity approaches, and during holding after harvest, destructive action may lead to actual loss of weight of the plant tissue. When held in common storage and in refrigeration above freezing, natural plant products such as seeds, tubers, roots, leaves, and fruits continue to live and undergo some of the changes associated with increasing maturity. In respiration, they give off carbon dioxide and water as products of the combustion of carbohydrate.

The rate at which these activities progress depends primarily upon temperature. The effect of a particular temperature varies with the product, but in general the lower the temperature the slower is the enzymatic action.

Nutritive Quality of Stored Fresh Fruits and Vegetables

The use of carbohydrate for respiratory activity as indicated in the previous paragraphs results in a net loss in energy value of plant tissues during storage, but this loss is comparatively small and unimportant from the standpoint of nutritive value. The effects of holding on other constituents of nutritional importance may be considerable in these foods even when the time is short.

Vitamin C is especially subject to loss during holding because it may be partly inactivated by respiratory enzymes present in all living tissues. The more perishable types of vegetables such as fresh spinach, lettuce, green corn, green peas, broccoli, cauliflower, kale, endive, and green beans lose their antiscorbutic value rapidly at room temperature. Spinach loses about half its ascorbic acid in three days and all in seven days. At low refrigerator temperatures, however, rate of loss is much slower.[18]

Packing leafy vegetables and broccoli with layers of crushed ice has been found to be very effective in promoting retention of vita-

[18] Tressler et al., *Food Res.*, 1: 3 (1936).

min C as well as in maintaining freshness of appearance. This practice is recommended to protect these vegetables during shipment and holding during subsequent steps in marketing.

Less perishable vegetables tend to lose vitamin C during storage at a slower rate, even at room temperatures. In one study, cabbage lost about one-third of its vitamin C when stored at room temperature 6 weeks and about the same proportion in 12 weeks at refrigerator temperatures (46 to 48 degrees F.; 8 to 9 degrees C.).[19] In another investigation, Danish Ballhead cabbage stored in a cellar where the temperature was approximately 45 degrees F. (7.2 degrees C.) for 6 months lost about one-fourth of its vitamin C.[20] Potatoes held in cellar storage until spring lose two-thirds of the vitamin C that they had at harvest.[21] Sweet potatoes, however, lose only about one-third of their original higher amount after both curing and storage.[22] Rutabagas and carrots show little loss of vitamin C by spring, but parsnips, even when held just above freezing, lose almost three-fourths of their vitamin C during winter and more at higher temperatures.[23] They also lose over half their fall value if held in the ground until spring.[24] Rutabagas are so outstanding among vegetables in their content of this vitamin that their use, especially in the raw form in salads, should be encouraged in the spring when other antiscorbutic foods are few.

Tomatoes are relatively perishable of course, but do not lose vitamin C when held at room temperature for as long as 10 days.[25] The vitamin C concentration of oranges and grapefruit may increase during the first few weeks of cold storage at 42 degrees F. (5.5 degrees C.), but after that the amount decreases slowly.[26]

Numerous workers have found that the vitamin C in apples decreases during holding, slowly at cold storage temperatures but reaching losses of a third of the original amount in 4 to 6 months

[19] Gould et al., *Food Res.*, 1: 427 (1936).

[20] Mayfield and Richardson, *Mont. Sta. Bull.* 379 (1940).

[21] *Minn. Agr. Expt. Sta. Tech. Bull.* 196 (1951).

[22] Ezell et al., *Food Res.*, 13: 116 (1948).

[23] Richardson and Mayfield, *Science*, 76: 498 (1932). Also, Richardson and Mayfield *Mont. Agr. Expt. Sta. Bull.* 277 (1935).

[24] Mayfield and Richardson, *Food Res.*, 5: 361 (1940).

[25] Maclinn et al., *Proc. Am. Soc. Hort. Sci.*, 33: 543 (1936).

[26] French and Abbott, *J. Nutrition*, 19: 223 (1940).

when temperatures average 35 and 38 degrees F. (1.67 and 3.33 degrees C.).[27]

So far as appropriate tests have been made, vitamins other than C in fresh fruits and vegetables are much less subject to inactivation during holding and common storage. Carrots in sand in cellar storage, whether warm and dry or moist and cool, and sweet potatoes stored at 50 to 60 degrees F. (10 to 15 degrees C.) have been found to suffer no loss in vitamin A activity. In refrigerated storage where humidity is not maintained to prevent wilting, the resulting dehydration is associated with some inactivation of provitamins A as well as vitamin C.[28]

In summarizing the evidence regarding the nutritive value of fresh perishable fruits and vegetables, particularly as purchased, it must be concluded that many factors operate to cause variation in food value, especially vitamin C content, before these products reach the kitchen. Careless handling at the farm, such as permitting them to stand exposed to the sun or holding them overnight in warm quarters, may make them lose over half their vitamin C in a few hours. Conditions of temperature, humidity, and time of holding during marketing may be responsible for additional losses of this vitamin. It is not surprising that market samples tend to be lower in vitamin C than the freshly picked. We must expect that winter vegetables which may have been harvested a week or longer when they arrive at the markets in our Northern cities are considerably lower in vitamin C value than locally grown in-season products. Precooling before shipment, refrigeration or icing during transportation, and refrigeration or other cool storage with humidity control, such as icing to prevent wilting, should be emphasized to retain maximum food values of perishables.

Digestibility of Stored Fresh Fruits and Vegetables

Storage probably has no significant effect on digestibility of fruits and vegetables.

Sanitary Quality of Stored Fresh Fruits and Vegetables

Low storage temperatures retard the development of bacteria, including pathogenic forms as well as those which merely make food inedible.

[27] Eheart, *Va. Agr. Expt. Sta. Tech. Bull.* 69 (1941).

[28] Harris and Mosher, *Food Res.*, 6: 387 (1941). Also Harris et al., *J. Lab. Clin. Med.*, 25: 838 (1940).

Palatability of Stored Fruits and Vegetables

Because unprocessed fruits and vegetables are living tissues undergoing continuous metabolic changes, it is to be expected that some of the chemical reactions involved would affect palatability. This is particularly true of flavor and texture, both of which have been shown to be altered by the time, the temperature, and the humidity conditions of holding.

Flavor. Holding temperatures affect carbohydrate transformations in vegetables and fruits and hence their flavor. When vege-

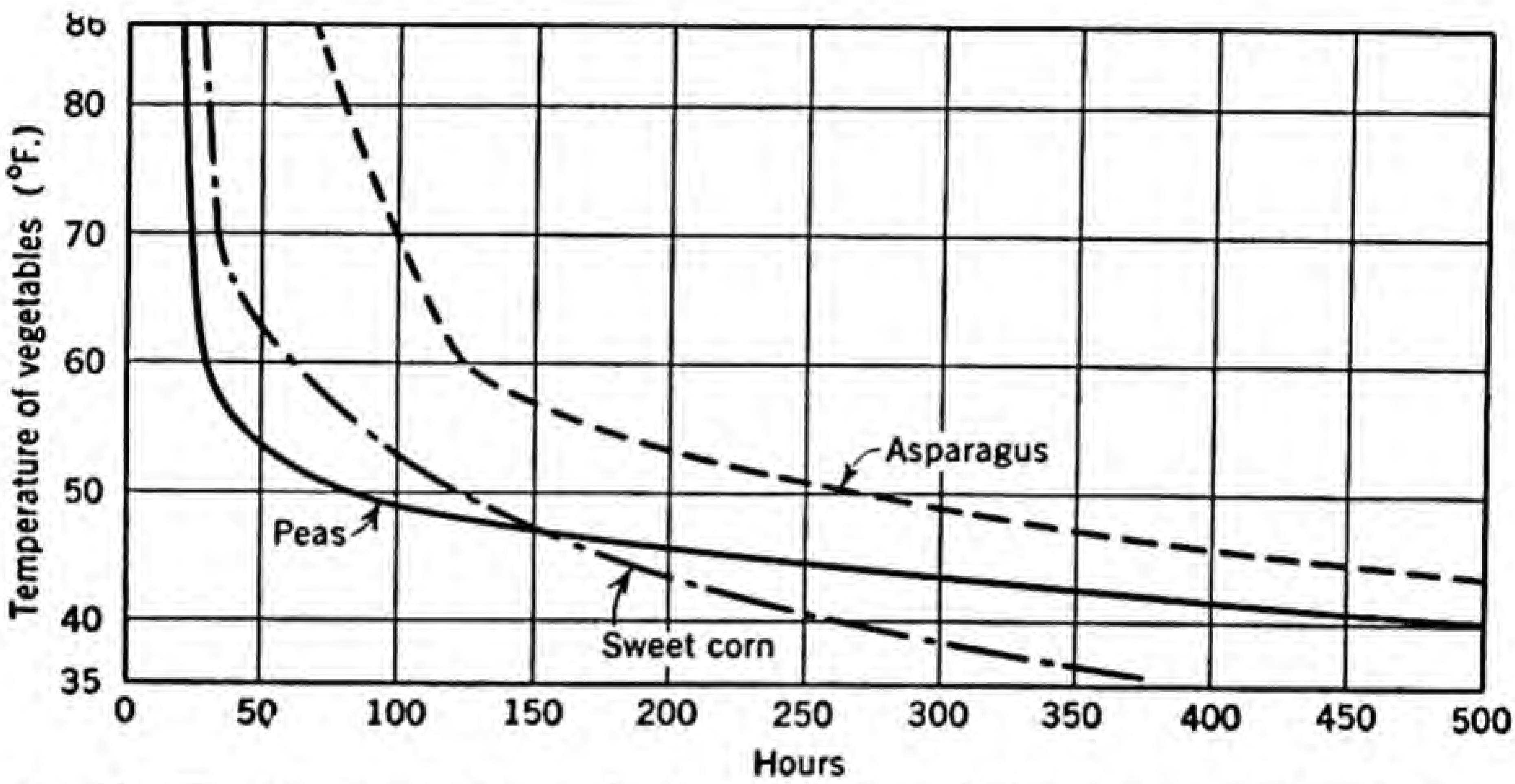

FIG. 10. Time-temperature curves showing the time required to produce a 30 per cent loss of the original sugar content of asparagus, sweet corn, and peas at different temperatures. (*Platenius*, 1939.)

tables containing a substantial amount of sugar, such as sweet corn, peas, and asparagus, are picked, production of new carbohydrate is stopped. Then the sugars present are both consumed in respiration and changed to other substances, particularly starch in corn and peas, and cell wall materials in asparagus. In general, loss of sugar is accelerated at higher temperatures, and experiments have shown that when the loss reaches 30 per cent, sweetness decreases very noticeably.[29] At 85 degrees F. (29.4 degrees C.), peas and corn, in particular, lose their sugar quite rapidly and may have their flavor altered markedly in less than 20 hours though they do not become unmarketable so far as external appearance is concerned for 110 hours. (See Fig. 10.)

[29] Platenius, *J. Agr. Research*, 59: 41 (1939).

In the potato, the transformation of sugar to starch is so much inhibited at temperatures below 45 degrees F. (7.2 degrees C.) that the opposite reaction of breakdown of starch to sugar, which is going on at all times slowly, gains over the sugar-to-starch reaction to the extent that sugar, especially reducing sugar which is largely dextrose, actually increases.[30] The amount of increase in sugar depends upon temperature, time, and variety. The increase may be sufficient to cause an objectionably sweet flavor and seriously injure frying color. Overbrowning has been attributed to a reaction between free amino groups and reducing sugar, but it may be in part a result of excessive caramelization. The effect on frying color is so marked in some varieties that it is impossible to store them at temperatures low enough [about 40 degrees F. (4.4 degrees C.)] to inhibit sprouting without developing so much reducing sugar that the tubers are unsuitable for chip making.[31] (See Table XXIII.) Excessive sugar also decreases mealiness when potatoes are cooked.

When such high-sugar potatoes are brought into a warm room, the sugar gradually diminishes through reconversion into starch and through loss in respiration. For culinary purposes, therefore, potatoes are best when stored at temperatures above 50 degrees F. (10 degrees C.), or when transferred from cooler temperatures to room temperature two weeks or more before use. The same accumulation of sugar at low temperatures occurs in parsnips and explains their lack of palatability in the fall as compared with that after a winter in the soil. The sweetness that develops when they are left in the field over winter is considered desirable and may be approximated by two weeks' storage at 34 degrees F. (1 degree C.).

In general, to secure the best flavor and nutritional value, fruits and vegetables must often be harvested at a time when rapid internal metabolic changes are tending to destroy qualities of palatability, to diminish nutritive value, and to promote invasion by decay organisms. Common storage merely retards deterioration, even when the temperature is just above the freezing point. Drying, canning, or freezing is necessary for extended preservation. Although cold temperatures which just avoid freezing might be expected to give the best results for storing fresh fruits and vegetables, because they retard internal changes most, they do not for some of these foods. As we have seen with potatoes, low temperatures unbalance the

[30] Appleman, *Md. Agr. Expt. Sta. Bull.* 167 (1912).

[31] Denny and Thornton, *Contrib. Boyce Thompson Inst.*, 11: 291 (1940).

Table XXIII. Reducing sugar content of juice of potato samples held under different storage temperatures

(After Denny and Thornton)

Variety	Milligrams of reducing sugar per cc. of juice									
	After storage from Nov. 24 to Jan. 9 at room temperature	After shortage which started on Dec. 1 and continued for			After removal from 5° and 10°, then after storage for 16 days					
		62 days at	57 days at	54 days at	At 15° C. (59° F.) after removal from			At 22°C. (71.6° F.) after removal from		
		5° C. 41° F.	10° C. 50° F.	15° C. 59° F.	5° C. 41° F.	10° C. 50° F.	15° C. 59° F.	5° C. 41° F.	10° C. 50° F.	15° C. 59° F.
Russet Rural	0.0	4.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chippewa	0.0	6.6	2.4	2.1	2.0	1.7	1.2	1.8	1.3	0.0
Katahdin	0.0	9.8	4.0	1.0	5.5	2.9	2.6	2.3	1.6	0.0
Carman No. 3	1.1	7.3	1.5	1.4	4.2	1.1	1.1	1.1	0.0	0.2
Irish Cobbler	2.2	8.3	2.2	2.3	4.7	1.2	0.7	2.6	0.0	1.3
Early Ohio	2.7	9.6	5.1	3.2	7.2	2.6	3.9	5.1	2.5	0.9
Russet Burbank	2.7	11.1	5.8	4.2	5.9	4.3	2.8	4.6	3.9	1.6
Blue Victor	3.0	13.0	6.9	3.4	7.0	3.9	2.3	5.3	2.3	2.0
Spaulding Rose	3.6	13.7	6.3	4.6	8.0	5.1	3.4	5.8	4.4	3.6
Green Mountain	5.9	13.5	6.6	6.1	6.6	5.9	3.6	4.0	4.6	4.2
Bliss Triumph	7.3	20.4	7.9	6.1	10.8	7.2	6.4	10.0	7.6	5.9

Note: The entry 0.0 means the amount was less than 0.2 mg. per cc. of juice. Potatoes were judged unsuitable for chip making when reducing sugar values were higher than 5.0 mg. per cc. of juice.

enzymatic changes and cause an undesirable accumulation of sugar. When ripening reactions are stopped by chilling, immature tropical fruits such as pineapple, papayas, bananas, and even tomatoes, will not ripen normally when returned to warm temperatures. The accompanying temperature ranges are recommended for holding different products.*

32 degrees F.–just above freezing (0 degree C.)	Apples, cantaloupe, cherries, peaches, pears, plums, quinces, raspberries, strawberries, asparagus, green beans, fresh Lima beans, beets, broccoli, cabbage, carrots, cauliflower, celery, green corn, garlic, lettuce, onions, parsnips, green peas, peppers, rhubarb.
35–40 degrees F. (1.6–4.4 degrees C.)	Cranberries, honeydew melons, oranges, potatoes for long storage.
40–45 degrees F. (4.4–7.2 degrees C.)	Ripe pineapples, ripe tomatoes.
50 degrees F. (10 degrees C.)	Grapefruit, cucumbers, potatoes in the fall or for immediate use; at other times, sweet potatoes.
55–60 degrees F. (12.7–15.5 degrees C.)	Squash, ripe bananas, lemons, mature green pineapple.
60–70 degrees F. (15.5–21.0 degrees C.)	Mature green tomatoes or unripe bananas for ripening.

Not all of these temperature ranges are likely to be available in the ordinary household, but a thermometer in the refrigerator or other storage areas may enable one to find a reasonable approximation.

Texture. Storage alters texture in plant tissue because of changes in the nature of the fiber and pectins and in the amount of water. Pectin changes are especially noticeable in fruits; fiber changes, in some edible stems, such as celery and asparagus. The firmness of immature fruits or vegetables that have not been held in storage is a result of their content of protopectin. During maturation and storage, protopectin changes to soluble pectins with a loss in cementing properties, which results in increased softness. An example of a change in fiber affecting texture is the woodiness that develops in asparagus shortly after cutting, especially if it is stored at high

* Rose et al., *U. S. Dept. Agr., Circ.* 278 (1949), revised.

temperatures. A change in the constituents of the cell walls renders the cellulose hard and stringy.

Texture in plant tissues is also affected by their water content. An equilibrium tends to be set up between the moisture content of the air and the moisture present in exposed materials. The point at which equilibrium is established depends on the nature of the materials, that is, their capacity to take up and hold moisture, and on the relative humidity of the air. Thus there is no wilting even of such vegetables as lettuce and asparagus at a temperature of 86 degrees F. (30 degrees C.) if they are kept in an atmosphere that is nearly saturated. Bunch carrots lose moisture much less rapidly when the tops are removed to cut down the evaporating surfaces. Potatoes lose water relatively rapidly when first harvested, but a natural development of corkiness in the skin soon slows down evaporation. Packing the more perishable vegetables with layers of crushed ice makes them stay fresh in texture longer as well as retain their vitamin A and C value better. In the household refrigerator, storage in moisture-proof bags or in a humidifier has the same advantages.

It has become an established commercial practice to reduce the loss of water in certain fruits and vegetables (citrus fruits, cucumbers, rutabagas, etc.) by treating them with wax emulsions.[32] Moisture-proof cellophane and other transparent plastics have also proved to be effective wrappings to retard water loss during marketing.

Economy of Stored Fresh Fruits and Vegetables

Storage of fruits and vegetables increases uniformity of supply and lowers out-of-season costs. The amount that the average family should store depends upon price or amount raised at home, adequacy of storage facilities, and availability of other methods of conservation. Common storage, if available in the household, is so much cheaper and easier than the various forms of processing for preservation, canning for example, that it should usually be utilized in preference to them whenever it is equally suitable.

Cooking Fresh Fruits and Vegetables

The most generally liked vegetables, aside from tomatoes, are nearly always cooked before eating, including potatoes, peas, corn,

[32] Mack and Janer, *Food Res.*, 7: 38 (1942).

and green beans. The changes sought in the cooking of both fruits and vegetables are principally those affecting palatability and sanitary quality. Cooking leafy vegetables is also useful to reduce their bulk and thus increase the food value per serving.

As it is often practiced, the cooking of vegetables gives a product lacking in appetite appeal and one markedly reduced in food value. Cooked fruits, for reasons which will appear later, are less subject to both types of depreciation, but, because increased consumption of vegetables and maximum retention of their nutritive quality are desirable, no branch of cookery deserves more attention. The tremendous volume of research devoted to vegetable cookery since 1930 has yielded solutions to many of the problems involved.

Fruits and vegetables contain water; consequently, no matter what method of heat application is used in their preparation, unless it is accompanied by pressure as in a pressure cooker, their internal temperatures never exceed, and, in fact, often do not reach, the boiling point before they are done. Boiled potatoes weighing 200 grams or less are done when their interiors reach 207 to 210 degrees F. (97 to 99 degrees C.); those weighing 300 grams or more reach only 194 to 203 degrees F. (90 to 95 degrees C.) at this stage. In evaluating these foods as processed by the usual forms of heating, we are thus studying the effect of temperatures somewhat lower than boiling.

The Nutritive Quality of Cooked Fruits and Vegetables

The problem of retaining as completely as possible the original nutritive values of vegetables and fruits when they are cooked has received the attention of many researchers. Their findings cannot be discussed in detail within the scope of this book, but the ability to make sound practical decisions about cooking procedures requires knowledge of the nature and extent of the losses to be expected under various conditions. We shall select examples of experimental findings to illustrate these phases of the problem.

Cooking losses to which fruits and vegetables are subject are of the two types previously mentioned—losses by *solution* and losses by *inactivation*. Of the two, losses by solution are the more readily controlled, but, in the case of vegetables, they are the more important cause of depleted food values in the average household.

Losses by solution occur whenever any cooking liquid, added water, or juice from the plant tissue is discarded. They are a result of the loss of semipermeability on the part of the cell walls and

protoplasm when the tissue is heated. As these components become permeable, substances in true solution tend to be leached from the tissue until the concentration of solutes in the surrounding liquid approaches that left within the tissues.

The soluble components of fruits and vegetables which have significant nutritive value include primarily the minerals: phosphorus, calcium, and iron; and the water-soluble vitamins: thiamine, riboflavin, niacin, and ascorbic acid. Carotenes are relatively insoluble in water; therefore a smaller proportion of them is dissolved in the cooking. Sugar is, of course, readily soluble, but vegetables contain little, and the cooking liquids from fruits are usually served with them. A small amount of protein also appears in the cooking liquids. It consists primarily of globulins which are soluble in salted water and albumins which are soluble in cold water although they are coagulated by heat. When cut surfaces are exposed to cooking water, larger dispersed components such as starch and additional protein escape from the plant tissue.

The food constituents dissolved in cooking liquids can, of course, be utilized by consumption of the liquids themselves, or they may be conserved by evaporation which leaves them on the surfaces of the vegetable. Palatable ways of serving cooking liquids include incorporating them in gravies, stews, soups, molded salads, using them to cook macaroni, spaghetti, or rice, combining them with tomato juice for cocktails, and seasoning and serving them in individual portions as "pot liquor."

The method of evaporation has some disadvantages. It requires skill and attention on the part of the cook to prevent overcooking the vegetable or to avoid scorching it, and it further increases losses of vitamin C by inactivation. With experience, however, one can learn to add a minimum proportion of water in the first place, to regulate the rate of evaporation by means of the cover, and to control the intensity of the heat so that disappearance of all cooking liquid which cannot be conveniently served with the vegetable is timed to coincide with doneness. Where the vegetable is done before evaporation is sufficiently complete, it is preferable to use the liquid in one of the above ways rather than to overcook the vegetable.

If the dissolved components are not to be conserved by one of the above methods, it is especially important to minimize them by adopting the following procedures: (1) adding little or no water,

(2) cooking without paring, (3) shortening the cooking period to a minimum.

Adding Little or No Water. Krehl and Winters measured the effect of cooking approximately 1-pound amounts of 12 vegetables to the same stage of doneness in varying amounts of water on losses of both minerals and vitamins. In the pressure saucepan, ½ cup of water was added; in "waterless" cooking, none was added. These methods were compared with boiling in water to cover and in ½ cup of added water. In all cases the pan was kept covered. Results of ascorbic acid and carotene losses are given in Table XXIV.

Table XXIV. The effect of cooking vegetables in varying amounts of water on losses of ascorbic acid and carotene

[Krehl and Winters, *J. Am. Dietet. Assoc.*, 26: 966 (1950)]

Vegetable	Per cent of ascorbic acid and carotene retained							
	Pressure cooked		Water to cover		½ Cup water		Waterless	
	Ascorbic acid	Carotene	Ascorbic acid	Carotene	Ascorbic acid	Carotene	Ascorbic acid	Carotene
Asparagus	67.6	78.5	45.2	64.6	66.4	92.3	69.4	101.5
Beets	93.8	81.4	74.0	72.4	87.3	82.8	81.1	96.2
Broccoli	68.0	88.6	50.6	76.0	68.7	84.3	70.2	97.7
Cabbage	75.5	96.8	44.3	73.3	57.4	89.7	68.4	95.6
Carrots	79.1	88.4	63.1	84.5	75.1	86.3	72.5	98.9
Cauliflower	75.5	89.8	47.3	80.7	54.0	83.7	70.7	97.4
Corn	74.9	88.2	60.2	86.4	65.1	87.3	69.6	93.1
Green beans	76.1	94.4	58.5	85.6	64.0	90.3	74.8	96.3
Peas	73.7	89.7	51.3	83.2	70.0	89.4	78.8	91.2
Potatoes	57.3	86.3	41.0	78.9	48.4	80.5	79.4	85.8
Squash	65.3	92.3	50.5	82.4	66.5	84.2	74.8	91.9
Spinach	61.7	74.8	49.1	80.7	51.7	87.2	70.0	91.3

These results show clearly that the greatest retention of both vitamins is obtained when vegetables are cooked without added water, and that least retention is associated with cooking in the largest amount of water, i.e. water to cover. Losses when a pressure saucepan or a small amount of water were used were intermediate. Other studies show that cooking by steaming above water gives

retentions similar to those for cooking in a pressure saucepan or in a small amount of water. Krehl and Winters also obtained data on the minerals: calcium, iron, and phosphorus; and the vitamins: thiamine, riboflavin, and niacin. Losses of these nutrients were in the same direction as those of ascorbic acid and carotenes so far as they were affected by the amount of water added. Also the percentage of other nutrients lost was usually more than that for carotene and less than that for ascorbic acid. Thus retention of ascorbic acid may be used as a measure of the relative desirability of a cooking procedure for these foods—if *it* is well-retained we may assume that all nutrients are well-retained and vice versa.

In waterless cooking, retentions of vitamin C in the 12 vegetables ranged from about 70 per cent to about 80 per cent. These data and those from many other studies demonstrate that it is possible to retain to a high degree the original nutritional value of a vegetable in cooking. On the other hand, so conservative an amount of water as enough to cover usually reduced the vitamin to half or less of the original. In any case, since nearly all the lost nutrients are in the cooking water, utilizing the cooking liquids is definitely worth the effort.

Cooking without Paring or in Large Pieces. As might be expected there is evidence that solution losses in cooking are affected by the amount of surface, especially cut surface, exposed to the water. The skins of potatoes are such an effective barrier that boiled or steamed whole potatoes show little loss of vitamin C. When peeled, losses may amount to about 13 per cent.[33] "Frenched" green beans (cut in lengthwise strips) retain only 28 per cent of the original vitamin C as compared with 54 per cent retention in those cooked whole, and 52 per cent retention in those cut in 1-inch lengths.[34]

To some extent, losses caused by increased surface resulting from cutting in small pieces are offset by the shortening of the time for cooking. In general, however, it is especially important to utilize cooking liquids when vegetables are cut into small pieces for cooking.

Shortening the Cooking Period to a Minimum. Shortening the entire heating period in cooking reduces solution losses by diminishing the time during which the food is exposed to the leaching action of the water. In cooking kale, for example, it was found that re-

[33] Van Duyne et al., *Food Res.*, 10: 72 (1945).

[34] Noble and Worthington, *J. Home Econ.*, 40: 129 (1948).

tention of ascorbic acid went from 51.4 per cent when it was boiled 6 minutes to 44.9 per cent at 9 minutes and 39.9 per cent at 13.5 minutes.[35]

Adding salt to vegetables during cooking tends to increase solution losses of vitamin C, according to the BHNHE, but in an amount that is so small that it may be added during or after cooking, according to flavor preferences.

Losses by inactivation in the cooking of vegetables and fruits involve the vitamins, especially ascorbic acid and, to a lesser extent, thiamine and riboflavin. In relation to ascorbic acid, inactivation is probably primarily the result of oxidation. The reaction is catalyzed by enzymes and proceeds more slowly after the stage of heating which destroys them. The amount of inactivation is known to be related to the hydrogen-ion concentration (acid solutions retard it) and to the amount of oxygen present, but differences in these factors do not entirely explain the variations in resistance of the vitamin in different foods. Furthermore, inactivation continues as heating is prolonged, whether in cooking or under conditions which keep the food hot until it is served. Losses continue when the cooked food is held in a refrigerator, and reheating produces additional inactivation. Probably other catalysts such as copper ions from the container or present in the food itself, which are not destroyed by heat, are responsible for at least part of the inactivation which takes place after enzymes have been destroyed.

Losses by inactivation are on the average much lower than those by solution. In 21 tests of 5 different vegetables, an English experimenter found that losses of ascorbic acid by inactivation averaged 9 per cent, but losses by solution averaged 61 per cent. Figure 11 illustrates the nature and proportion of losses of vitamin C in the cooking of peas. Whereas 40 per cent of the original amount was in the cooking water when the peas were done, 53 per cent was in the peas, leaving only 7 per cent lost by inactivation.[36] In a study of the cooking of carrots, results were similar. The boiled vegetable retained about 56 per cent of the original vitamin, about one-tenth was inactivated, and the rest was in the cooking water.

In general, practical methods of minimizing losses by inactivation include (1) shortening the period of preboiling temperatures to

[35] Potgieter and Greenwood, *Food Res.*, 15: 223 (1950).

[36] Fenton et al., *J. Nutrition*, 12: 285 (1936). See also Gould and Tressler, *Food Res.*, 1: 427 (1936).

hasten the destruction of enzymes, (2) shortening the entire periods of heating, including both the cooking time and the period of standing before serving, (3) avoiding the accumulation of leftovers which require storage and reheating, and (4) carefully restricting any addition of soda to intensify greenness or promote softening.

Shortening the Period of Preboiling Temperatures to Hasten the Destruction of Enzymes. Vegetables should be brought to a boiling temperature rapidly for maximum retention of vitamin C. This is facilitated by (*a*) having any water which is added hot, (*b*)

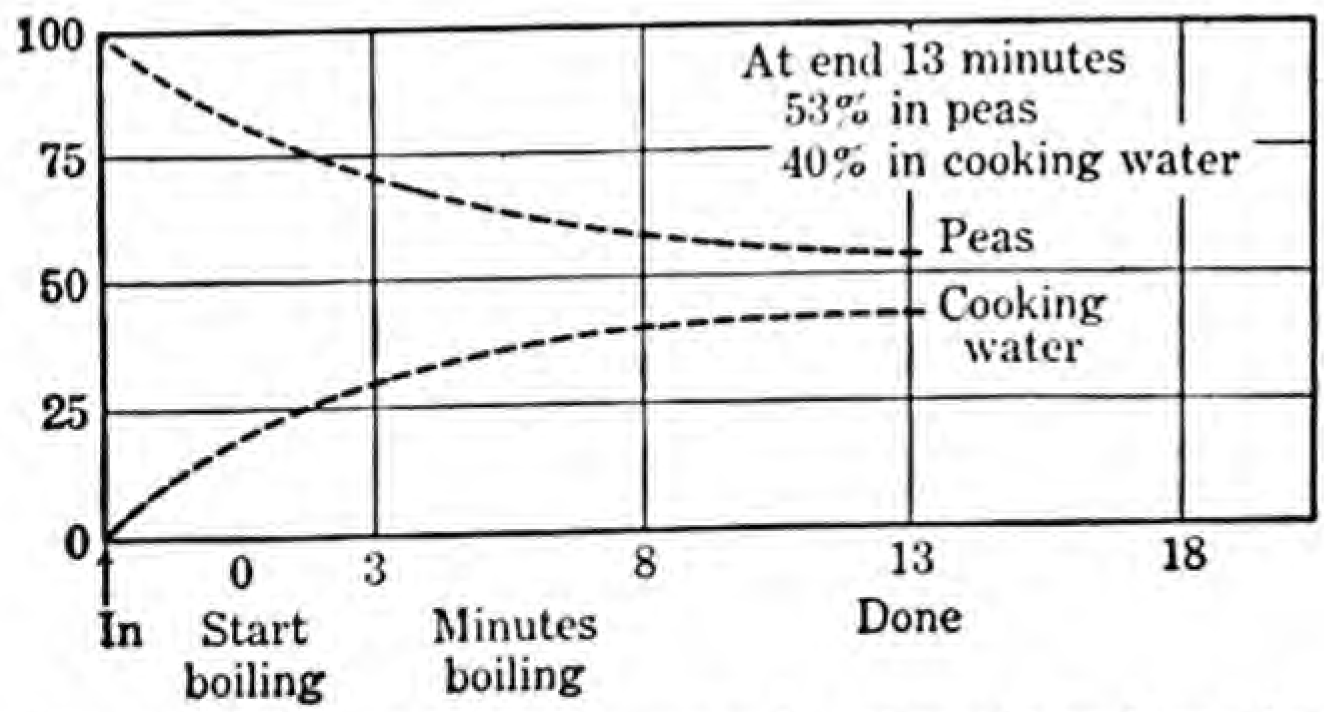

FIG. 11. Types and amounts of losses of vitamin C during the cooking of peas. (*Fenton et al.*, 1936.)

using high heat until boiling is reached, (*c*) cooking with a cover, (*d*) cooking in quantities suited to the utensil and source of heat, (*e*) using a pan with a large area in contact with the source of heat, and (*f*) using water or steam as the cooking medium. So-called "waterless" cooking of vegetables is cooking in the steam from the vegetable itself. When air is the cooking medium, as in an oven, heating is slow and as a result baking vegetables or cooking them in a casserole results in considerable losses of vitamin C by inactivation. Whereas boiled or steamed potatoes cooked in their skins lose none of the vitamin, baked potatoes lose 12 to 22 per cent.[37]

Shortening the Entire Heating Period, Including Both the Cooking Time and the Period of Standing before Eating. Overcooking increases losses by inactivation as well as by solution. The principal disadvantage of the pressure saucepan method of cooking vegetables is the special care required to prevent overcooking. If cooking is stopped at the "just-done" stage, both nutritive quality

[37] Van Duyne et al., *Food Res.*, 10: 72 (1945).

and palatability may equal that by any other method.[38] Baked potatoes which averaged 88 per cent retention of ascorbic acid when done, lost an additional 6 per cent when held 1 hour, and 39 per cent when held 4 hours on a steam table.[39]

Many studies show substantial losses of this vitamin in other vegetables under similar conditions. When cooked vegetables must be held before serving, it is probably better from the standpoint of nutritive quality as well as palatability to cool and then reheat them quickly than to hold them on the back of the stove.

Avoiding the Accumulations of Leftovers Which Require Storage and Reheating. Holding cooked vegetables or cooking liquids in a refrigerator results in further losses of vitamin C. When peeled and halved potatoes which had lost 13 per cent of their vitamin C during boiling were held in a refrigerator 24 and 70 hours, additional losses of 40 and 69 per cent resulted.[40] Hash-browning potatoes that have been held in a refrigerator overnight inactivates about one-fourth of the remaining vitamin.[41] Cooked cabbage containing 57 per cent of its original vitamin C retained 29 per cent after storage in a refrigerator for 24 hours followed by reheating and 24 per cent after similar storage for 72 hours and reheating.[42]

Cooking liquids from a number of vegetables have been found to lose part of the vitamin during storage in a refrigerator and more on reheating. Thus the liquid from peas lost about three-quarters of its ascorbic acid in 2 days and another third of this in being brought to a boil.[43] It should be emphasized, however, that aside from possible losses of thiamine, leftover cooked vegetables and cooking liquids retain other nutrients and would be well worth conserving even if they had lost all their vitamin C.

Restricting Any Additions of Soda. As will be mentioned in the section on palatability of cooked fruits and vegetables, soda is sometimes added in the cooking of green vegetables to intensify their color. Workers at the BHNHE found that less than one-eighth of a teaspoon of soda added to the cooking water with 1½ pounds of peas produced no loss of vitamin C. However, this is an amount of

[38] Van Duyne et al., *J. Am. Dietet. Assoc.*, 27: 1059 (1951).
[39] Streightoff et al., *J. Am. Dietet. Assoc.*, 22: 117 (1946).
[40] Van Duyne et al., *op. cit.*
[41] Hewston et al., *U. S. Dept. Agr., Misc. Pub.* 628 (1946).
[42] Van Duyne et al., *Food Res.*, 9: 164 (1944).
[43] Sutherland et al., *Food Res.*, 12: 496 (1947).

soda which is very difficult to measure accurately, and peas differ from most other vegetables except fresh Lima beans in having a relatively tough outer coat.[44] Excessive amounts of soda not only increase inactivation of ascorbic acid but impair flavor and induce mushiness.

One other practice which promotes inactivation of vitamin C is incorporation of air as in mashing potatoes. Mashing alone inactivates from one-quarter to one-half of the vitamin left after cooking, and further loss takes place relatively rapidly on standing.

Digestibility of Cooked Fruits and Vegetables

Cooking makes some celluloses slightly digestible. Cooked fruits and vegetables do not contribute as much bulk as the raw; therefore those people who require extra roughage to prevent constipation find the raw more helpful. On the other hand, those children and adults who digest certain raw vegetables only very incompletely usually find that they have no difficulty with the cooked products. The digestibility of other components may also be increased by the disintegration of cellulose in cooking.

Vegetable starches such as that of the potato have large granules, and in the raw form are relatively resistant to the action of digestive enzymes. Bacterial fermentation in the intestine after eating raw potatoes may produce discomfort from gas, and a considerable part of the starch is excreted in an indigested form. Thus cooking is desirable to increase digestibility.

In studies of the time that food remains in the stomach, it has been found that the average time in the stomach for a large number of cooked vegetables is 2 hours for individuals classified as the "rapid-emptying" type and 2½ hours for those of the "slow-emptying" type.[45] Vegetables high in starch, such as potatoes, show some digestion of the starch before leaving the stomach. In general, cooked vegetables stay in the stomach long enough to result in considerable disintegration in contrast to the small amount of change reported in raw vegetables in the short time that they remain there. The effect of the method of preparation of potatoes on the length of time required for emptying the stomach of human subjects after consumption of 100 grams (average serving) has been studied.[46]

[44] Hewston et al., *op. cit.*

[45] Miller et al., *Am. J. Physiol.*, 51: 332 (1920).

[46] Boggess and Ivy, *J. Home Econ.*, 19: 496 (1927).

The average time for several subjects was 2.5 hours for French-fried potatoes containing 7.18 per cent of fat, 2.8 hours for pan-fried containing 12.55 per cent of fat, 2.8 hours for boiled containing no added fat, and 4.3 hours for boiled with 37.5 per cent added fat. Evidently the method of cooking had little effect on the time that the potato remained in the stomach, but, if large amounts of a fat in gravy or butter were eaten, considerable delay resulted. In evaluating the results of such experiments we should remember that not all digestive disturbances arise while food is in the stomach, and that such work does not prove that methods of preparation do not differ in their effect on total time required for digestion or other properties.

In regard to vegetables of the cabbage family, it has been shown that the discomfort which some people suffer after eating them is in nearly all cases a result of overcooking. Finely shredded raw cabbage and cabbage and cauliflower cooked only until tender caused discomfort in only 1 of 20 persons selected for study because they had difficulty with these foods.[47]

In regard to discomfort associated with eating onions, raw onions have been found to be more likely to cause disturbance than cooked onions. But cooking in an open kettle only until the vegetable is tender gives a product less likely to be at fault than cooking for as much as 1½ hours in a closed kettle.[48]

Sanitary Quality of Cooked Fruits and Vegetables

Ordinarily, freshly cooked fruits and vegetables are among our safer foods so far as the presence of harmful microorganisms or their toxins is concerned. Such foods, especially the nonacid vegetables, are, however, excellent media for bacterial growth and, if contaminated, may become unwholesome on standing. The outer portions of many fruits should either be discarded or carefully washed to remove the spray residues before they are cooked.

Palatability of Cooked Fruits and Vegetables

Flavor. It is usually desirable to regulate the cooking of fruits and vegetables to retain as much of the natural flavor as possible. The volatile flavoring substances are partly driven off by heat. Others are water-soluble and appear in the cooking liquids. Short-

[47] Hughes and Campbell, *J. Am. Dietet. Assoc.*, 15: 24 (1939).

[48] Hughes and Harris, *J. Am. Dietet. Assoc.*, 18: 815 (1942).

ening the cooking period minimizes both types of loss. The addition of only small amounts of water, or conservation of the liquid portion by using it in the sauce served with the vegetable or by evaporating it to serve on the vegetable, aids in the prevention of loss of flavor by solution. The flavor of the juices and cooking liquids of fruits are so well liked that they are commonly served with the fruit.

In a few vegetables, flavor is improved by promoting losses by volatilization, as in boiling in an uncovered pan, or by solution, as in cooking in water which is discarded. Onions and garlic contain a sulfur compound which is responsible for their unpleasant aftertaste and breath odor, and which is both soluble and volatile. In onions, it can be diminished by boiling in an uncovered pan, and by discarding the cooking liquid, but this is seldom necessary and, of course, results in solution losses of nutrients. When onions or garlic are to be used in foods which do not reach the boiling point, their flavor can be distributed and blended by dividing them into small pieces. The immediate aftertaste and breath odor which follow the eating of both onions and garlic may be a result of food particles retained in the mouth and which are not removed by ordinary brushing or mouth washes. Experimental evidence indicates, however, that, after digestion, the odoriferous component of the portions which have been swallowed are transferred to the air passages and may be evident on the breath for many hours.

Vegetables of the cabbage family, including broccoli, Brussels sprouts, and turnips, contain such sulfur compounds as the glucoside *sinigrin*. This has a relatively mild flavor in the combined state, but as a result of high temperatures or of prolonged cooking, it decomposes to form hydrogen sulfide and other compounds which give strong flavors and, for some persons, uncomfortable physiological reactions. The problem can be avoided if these vegetables are cooked rapidly and for as short a period as is considered desirable for palatable texture. When cut in small pieces, 5 minutes is usually enough for new cabbage, 7 or 8 for winter cabbage, and about the same for cauliflower. The presence of acid also accelerates the decomposition of the glucoside. Hence vinegar, if used, should not be added until cooking is nearly ended.

Color. The color of cooked vegetables and fruits is largely controlled by the nature of the original pigments, their solubility in the cooking medium, the acidity of the cooking medium, the length of the heating period, and the presence of certain metals. The cooking medium is alkaline when permanently hard water is used or

when baking soda is added. On the other hand, the plant tissues themselves contain organic acids and acid-forming substances which are freed and dissolved during cooking. These include oxalic, malic, and citric acids, which are not volatile; and formic and acetic acids, and hydrogen sulfide, which are volatile. The volatile products tend to escape unless confined by a cover. Metals, iron for example, may be dissolved from a pan in sufficient amounts to alter the color of certain pigments.

Green color is almost insoluble in water but is unstable in the presence of acids and heat. Unless the tissues are ruptured, it is not found in the cooking water to any extent. Added acids or those from the plant tissue itself, especially if a cover is used during cooking and the period of heating is more than a few minutes, or if the temperatures are those of a pressure cooker, cause the chlorophyll to decompose to form *phaeophytins*. These give an olive-green or brownish color that is unappetizing in appearance. Alkalies change chlorophyll to bright green *chlorophyllins*. Baking soda, if added to green vegetables, neutralizes the organic acids and produces the chlorophyllins, but, unless the amount is very small, it causes undesirable changes in textures and flavors; in excess, it may also increase inactivation of ascorbic acid and thiamine.

When fresh spinach has been in boiling water or steam for a short period, it appears much greener than when raw. Probably this is a result in part of driving air from the tissues or otherwise making the tissues more transparent, so that the green is less obscured, and, in part, of physical changes in the condition of the chlorophyll. If the heating is continued long enough, the olive-green or brownish-green color of phaeophytins develops.

When green vegetables are cooked in contact with copper, the copper forms compounds with chlorophyll which give a deep green color. Copper salts have been used for this purpose, particularly in the canning of vegetables, but, because of the poisonous nature of the salts themselves, their use is prohibited for commercial purposes in this country.

The best method to retain desirable color in foods containing cholorophyll is to keep the cooking period short. This is facilitated by cooking small lots in a shallow pan with a bottom which fits the heating unit. Frenching green beans and slitting the stems of asparagus or broccoli speed up cooking and make it possible to retain their color. Green vegetables, especially, look better when served

promptly. Color changes in chlorophyll are irreversible; when they have occurred nothing can be done to restore greenness.

The anthocyanins are soluble in the plant sap and consequently in added water. As already stated, they tend to be red in strongly acid solutions, becoming purple and greenish in more neutral and alkaline solutions. Metal salts derived from cooking utensils may cause the anthocyanins to shift in color towards the blues and greens. Retention of the self-contained volatile acids by covering the pan, or addition of acids during cooking, tends to make fruits and vegetables containing these pigments more intensely red, which is usually considered desirable.

In cooking red cabbage it is necessary to add acid if the vegetable is to be prevented from turning purple, but beets remain red in a solution of the degree of acidity provided by the cooking water. Color changes in anthocyanins produced by alteration of the hydrogen-ion concentration are reversible and hence can be adjusted in the cooked products.[40] When the yellow flavones are present, the anthocyanins may produce brownish tints.

As already mentioned, the carotenoid pigments give color to yellow or orange fruits and vegetables and are associated with chlorophyll wherever it occurs. When the chlorophyll is destroyed, the yellow of the carotenoids is visible, giving a yellowish-orange or brownish-green color to the product. These pigments, like chlorophyll, are not soluble in water. Unlike it, they are very stable towards heat, acid, and alkali. Sometimes during the cooking of carrots in the absence of water, a brownness develops, but this is caused by the caramelization of sugar, not by a change in the pigments.

The flavones and flavonols are water-soluble and almost colorless in the very dilute solutions in which they often occur in plants. Their yellow hue is intensified by alkaline media, including hard water, and diminished by acid. In the presence of iron they turn an unpleasant green or brownish hue. This may be observed when white or yellow onions are cooked in an iron utensil. The change is increased by long cooking.

Other changes which are neither related to the groups of plant pigments just mentioned nor to the caramelization of sugars may develop in cooked foods such as potatoes. Darkening or blackening of cooked potatoes is one of the most common complaints made

[40] Pratt and Swarthout, *Science*, 71: 486 (1930).

about their quality by consumers. One serious type in which the darkening follows an irregular pattern and develops during cooking is caused by the potato disease, *net necrosis*, and may make the entire tuber appear inedible. The more common type of darkening in potatoes develops while the cooked tuber stands and results in a more or less extensive area of blackened surface and interior centering about the stem end. It seems to be primarily a variety characteristic; some varieties (Sebago and Chippewa) do not darken, others (Rural New Yorker and Russet Rural) frequently darken, and still others are intermediate (Green Mountain, Katahdin, Cobbler and Russet Burbank).[50] This type of darkening is believed to be an oxidation of an iron compound freed in cooking. Unlike the changes in color of the cut surfaces of certain raw fruits and vegetables, it cannot have been caused by enzymes because these are inactivated by the heat of cooking. Acidifying the cooking water with vinegar, lemon juice, or cream of tartar, prevents blackening in potatoes having a relatively slight tendency to develop it. Adding ¼ teaspoon of cream of tartar to each two cups of water when potatoes are half-cooked is effective.[51] Mashing darkened potatoes with milk lightens their color, and adding ¼ teaspoon of cream of tartar during mashing is particularly effective.

Texture. As already explained, texture in plant tissues is chiefly conditioned by the fibrous framework of the cells, which are cemented together with pectic substances. Literature on the effects of cooking on vegetables frequently contains statements about the breaking of the plant cells, or other implications that the cell walls are ruptured during cooking, but careful microscopic examination shows that this is not usually the case. Changes in texture that develop during heating include softening of the cellulose, breaking down of hemicelluloses, solution of pectins, and gelatinization (swelling) of the starch. In plant tissues of high water content, such as leaves and tomatoes, another texture change is the loss of crispness associated with the loss of water which heating induces. When the deposit of lignin in cell walls causes woodiness in plants (asparagus, for example) they cannot be softened by cooking.

The hemicelluloses deposited in the cell walls add to their rigidity and may be partially dissolved during cooking, especially if a base such as soda has been added. Cellulose is noticeably softened, and

[50] Rieman et al., *J. Agr. Research*, 69: 21 (1944).

[51] Bowman and Hanning, *J. Agr. Research*, 78: 627 (1949).

since there is some increase in digestibility of the fibrous portions of plants after cooking, there may be a small amount of decomposition of this component. The resistance of the more mature vegetables to softening is probably a result both of increased fiber content and of its interference with the hydrolysis and solutions of the pectins.

During cooking, part of the pectins already present and those produced by the hydrolysis of protopectin may dissolve and lose their cementing power. Such vegetables as eggplant and tomatoes break up after only a short period of cooking because their pectins are easily dissolved.[52] The pectins of the cell walls have been shown to be more soluble than those in the middle lamellae. This probably explains why many vegetables soften without disintegration as they cook. The data in Table XXV show the nature and extent of the changes in the pectins of carrots during cooking.[53]

Table XXV. Effect of steaming on pectic substances of carrots *

(After Simpson and Halliday)

	Sample of carrot		
Fraction of pectic substance	Raw	Steamed 20 minutes	Steamed 45 minutes
Pectin	3.7	6.0	8.8
In cooking water	0.0	0.1	0.5
In vegetable	3.7	5.9	8.3
Protopectin (indirect method)	14.1	9.1	3.6
Pectic acid (or pectates)	0.8	1.0	1.3
Total pectic substances	18.6	16.1	13.7
In cooking water	0.0	0.1	0.5
In vegetable	18.6	16.0	13.2

* Results represent the per cent of dry weight and are computed from the average of five weights of calcium pectate in each case.

Acids added to vegetables during cooking retard softening, probably because they precipitate pectin. Thus beets should be softened by cooking in plain water before vinegar sauces or pickling solutions are added.

Sweet varieties of apples do not break up during the same period of cooking that causes disintegration of more acid varieties. This has been attributed to the presence in the former of more calcium

[52] Culpepper and Moon, *J. Agr. Research*, 47: 705 (1933).

[53] Simpson and Halliday, *Food Res.*, 6: 189 (1941).

pectate, which is insoluble. Most people prefer the superior flavor of the acid varieties of apples for baking, in spite of their greater tendency to crack open.

The behavior of fruits towards cooking in sugar sirups varies with the kind and sometimes the variety of the fruit as well as the concentration of the sirup and time of heating. The cell walls of fruits which have been pared or sliced are semipermeable membranes. Water is withdrawn from the fruit by osmosis with resulting shrinkage when the sugar concentration in the sirup is high at the beginning. If the sugar concentration is about equal to the concentration of solutes in the fruit, the fruit will retain its shape. When the fruit is cooked in plain water or a very low concentration of sugar, water may pass into the fruit and cause the cell walls to break. As the fruit cooks, the permeability to sugar increases. Thus when one wants plump, highly sweetened fruit as in preserves, it is well to start with a dilute sirup and add more sugar as cooking proceeds.

Desirable texture qualities in cooked potatoes include appropriate mealiness and freedom from breaking or sloughing. A high degree of mealiness is desirable in baked, steamed, or mashed potatoes. A less mealy or more waxy texture is suitable for salads or creaming. A high degree of mealiness tends to be associated with high starch content, but, when a number of samples are cooked under uniform conditions, the relative rank for mealiness does not always correspond with the rank for starch or dry-matter content. Some of the physiochemical changes taking place during the cooking of potatoes include partial gelatinization of the starch, softening of the cellulose, and solution of the pectins, but a complete interpretation of the development of mealiness has not been achieved.

Microscopic examination shows that the clearly defined starch granules scattered through the cells of uncooked potato tissue swell during cooking and appear to press against the cell walls on all sides. This pressure probably promotes separation in the softened middle lamella, but individual cells remain for the most part intact. When potatoes are excessively manipulated during mashing they become sticky and pasty, instead of retaining the characteristic granular texture of lightly mashed, mealy tubers. This is probably because the cells break, permitting the starch to escape. Perhaps excessive mashing also ruptures the starch granules, freeing the colloidal starch in the interior. Studies of the nature and amount of pectins present, of the factors affecting adhesion of the cells, and

of the gelatinization of the starch have not revealed any relationship between them and mealiness. In general, mealy potatoes tend on mashing to form a mass of unbroken cells with little free gelatinized starch, whereas pasty mashed potato includes more broken cells and free gelatinized starch.

Although certain varieties, the Idaho Russets (Netted Gem) and the Green Mountain for example, tend to be relatively mealy when compared with others grown under similar conditions, varieties which are nonmealy when grown in one environment may be mealy when grown elsewhere. Thus Chippewas grown in Aroostook County, Maine, are nonmealy, but samples grown in Idaho have been found to be relatively mealy. Maturity is significant in its effect; in general, the more mature the tuber, the more mealy it is when cooked. The effect of storage temperature on mealiness of potatoes has been mentioned previously. (See page 226.)

Probably potatoes of all varieties diminish in mealiness within 15 to 30 minutes on standing after they are cooked. Holding produces distinct loss in palatability, even when the potatoes are slit, slightly crushed to allow the steam to escape, and held in a warm oven. Cold potatoes are never mealy, nor do they acquire mealiness when reheated.

Sloughing of potatoes is most noticeable when they are pared and cooked by boiling and may vary in degree from a slight amount of scaling on the pared surface to breaking into several pieces. It is not always the result of overcooking and often occurs before the individual portions are done at their centers. Tendency to slough is more characteristic of mealy than nonmealy potatoes, although occasionally a very mealy sample does not slough at all. It is most troublesome in the fall for a few weeks after digging. Storing tubers for fall use at warm temperatures [65 degrees F. (18.3 degrees C.) or higher] accelerates the disappearance of this difficulty.

Sloughing has been attributed to the high turgidity of the tubers resulting from high water content, which makes them inelastic and subject to strain on heating. According to this theory, the evaporation of water during storage is responsible for the decreased tendency to slough. Sloughing has been prevented experimentally by employing an artificial hard water made with calcium sulfate, but the use of other methods of cooking such as baking and steaming in the skins also minimizes the problem.[54]

[54] Pyke and Johnson, *Am. Potato J.*, 17: 1 (1940).

There is no all-purpose potato, and perhaps in the future the market will supply us with more specialized kinds. Thus far, information about variety, area of production, and specific gravity, as a measure of starch content, give the best indication of probable mealiness. A simple specific-gravity method of separating mealy from nonmealy potatoes consists in putting washed potatoes in a salt solution of 1 pound of salt in 1 gallon of lukewarm water. Tubers that sink tend to be more mealy.[55] The amount of reducing sugar present is especially important if the tubers are to be used for frying, but should not be high enough to give a noticeable sweet flavor by any method of preparation.

To summarize, standards for cooked vegetables which specify some degree of crispness rather than complete tenderness describe a product which is generally attractive as well as nutritious. Overcooking of vegetables is probably responsible for much of the lack of appeal which discourages their consumption by many people. It is also the cause of much unnecessary waste of valuable nutrients.

Economy of Cooked Fruits and Vegetables

Cooking fruits and vegetables adds two costs to the preparation of the fresh product—time and effort in doing the cooking and the cost of the fuel. Shortening the time of cooking as recommended both for conserving nutritive value and developing appetite appeal also reduces the time required for supervision. If vegetables are cut into sufficiently small pieces, most of them can be cooked in 20 minutes or less. A pressure saucepan shortens cooking time of vegetables but this is of little significance when one considers the preheating and cooling periods and the closer supervision required.

Using high heat after a vegetable has come to boiling, cooking in an excessive amount of water, and cooking past the recommended stage of doneness are all wasteful of fuel. In general, improved practices in cooking vegetables save rather than cost extra time and money.

SELECTION AND USE OF FROZEN FRUITS AND VEGETABLES

Freezing is a method of preservation of fruits and vegetables in which the living plant tissue is killed either directly by the freezing

[55] Cobb, *Pa. Agr. Expt. Sta. Bull.* 464 (1945).

or beforehand by blanching. (See Chapter 7.) Freezing itself does not destroy self-contained enzymes nor do the temperatures of frozen storage entirely stop their action. In such foods, enzyme activities cause serious deterioration in eating quality and in the potency of ascorbic acid and carotenes during holding and must be destroyed by preliminary blanching.

Altogether there are four or five steps in the ordinary processing and preparation of frozen fruits and vegetables which may alter their value in use. These include (1) prefreezing treatments, (2) freezing, (3) holding, (4) thawing, and (5) cooking.

Prefreezing Treatments. Prefreezing treatment of frozen fruits and vegetables that may affect their value in use include blanching, concentration as applied to juices, and the addition of other substances such as sugar or sugar sirup, ascorbic acid, etc. Unfortunately, blanching like cooking—though to a lesser degree—leaches out part of the water-soluble components. Steam blanching is preferable to hot-water blanching because it causes smaller losses. Vegetables frozen without blanching deteriorate in color, flavor, and nutritive quality as a result of enzyme activities. Electronic blanching shows promise of becoming commercially practicable and has the advantage of eliminating solution losses.[56]

As mentioned in Chapter 7, fruits are seldom blanched but may be treated with sulfur dioxide, a sulfite dip, or ascorbic acid to retard enzymatic browning. Oxidation of the ascorbic acid is responsible for its protective action and little is likely to be left to supplement the nutritive value of the original product. Added sugar also tends to favor retention of color and flavor and to protect the ascorbic acid.

The Freezing Process. The actual freezing appears to have little or no effect on nutritive quality. As mentioned in Chapter 7, the rate should be fast enough to freeze the entire package in at most 12 hours, or deterioration in palatability may be evident.

Holding Frozen Fruits and Vegetables. Frozen fruits and vegetables lose palatability and ascorbic acid continuously during holding, but at a rate which is retarded as the storage temperature is decreased. Zero degree F. (−18 degrees C.) is suitable for the usual period of less than a year, but −10 degrees F. (−23.3 degrees C.) gives even better results.[57] At 15 degrees F. (−9.4 de-

[56] Moyer and Stotz, *Food Technol.*, 1: 252 (1947).

[57] Woodroff and Shelar, *Refrig. Eng.*, 56: 514 (1948).

grees C.) deterioration may be rapid. In one test, in 2 months at 10 degrees F. (−12.2 degrees C.) green beans lost 40 per cent of their vitamin C value. Losses of vitamin C are a good measure of undesirable changes in palatability. When commercial frozen fruits and vegetables are held in a household refrigerator compartment that is no lower than this temperature, they should be used within 10 days.[58]

Fluctuating temperatures above 0 degree F. during storage produce undesirable freezing and thawing of part of the ice crystals. Variations in temperature are responsible for frosting on the surface of the food, which indicates desiccation and greater tendency to drip on thawing. However, in one experiment, there was no difference in quality and ascorbic content of green beans and strawberries which were stored at a constant temperature of 0 degree F. (−18 degrees C.) and those stored at temperatures which fluctuated between this temperature and 10 degrees F. (−23.3 degrees C.) for 40 weeks.[59] Apparently, so long as the temperature is as low as 0 degree F. for a substantial portion of the time, some fluctuation is not harmful to at least certain fruits and vegetables.

It would be desirable if consumers could be warned that frozen food had undergone actual thawing on account of its unfavorable effects on nutritive value, palatability, and possibly on sanitary quality. A device based on use of a small capsule of a gel on the surface of the package, which melts and shows a visible change after such an episode, has been suggested.[60]

Thawing Frozen Fruits and Vegetables. Electronic thawing of frozen products is the most rapid method and shows promise for commercial use. In the household, frozen vegetables (except corn on the cob) may be thawed during cooking. In any case, they should be cooked promptly when once thawed. Frozen fruits may be thawed in a refrigerator or more rapidly at room temperature, or by placing the sealed bag in running water or in front of a fan. They should be eaten as soon as the ice has melted. Prompt cooking or eating of these foods is primarily necessary for retention of best palatability; also extended standing in the thawed stage reduces nutritive quality and permits development of bacteria which cause spoilage and possibly lower sanitary quality, as will be discussed later.

[58] Tressler, *Prac. Home Econ.*, 29: 27 (1951).

[59] Ehrenkranz and Roberts, *J. Home Econ.*, 44: 441 (1952).

[60] Ramstead and Volz, *Food Inds.*, Vol. 22, No. 12, p. 84 (1950).

Cooking Frozen Fruits and Vegetables. Ordinarily only frozen vegetables are cooked. With a pan of proper type it is not necessary to use as much water as called for on commercial packages. Frozen vegetables when once thawed, cook in one-third to one-half the time required for their fresh counterpart, because blanching has started the process and because freezing disrupts the tissues.

The same practices recommended to retain nutritive value and produce high eating quality when cooking fresh vegetables are also recommended for cooking frozen vegetables. Boiling in a very small amount of added water with the cover on gives good results. To obtain uniform cooking the frozen mass should be broken apart as soon as possible. Partial prethawing helps ensure uniform cooking of compact frozen products like spinach. Overcooking should be avoided.

Appraisal of Frozen Fruits and Vegetables

The standard for comparison in evaluating frozen fruits and vegetables might be either the fresh product or the fresh product preserved in some other way, especially by canning.

Nutritive Quality of Frozen Fruits and Vegetables

Solution losses occur in frozen products which are blanched or cooked. Inactivation losses take place during holding in frozen storage as well and depend upon time and temperature of holding. They are accelerated in the thawed product which is allowed to stand. Further losses take place in cooking. The following percentages of retentions of vitamin C were found at each stage of processing of frozen peas:

After blanching	85 per cent
After cooling	78
After quick freezing	78
After storing 1 month	79
After storing 3 months	70
After storing 6 months	59
After storing 9 months	53
After cooking	32
In cooking water	10

Thus frozen peas which had been held in frozen storage 9 months retained about one-third of the original vitamin after cooking, or a

little less than half of the original if the cooking water was conserved. Losses of ascorbic acid in spinach were higher, primarily because loss during blanching and cooking was very high (54 per cent). When it was stored 6 months and cooked, the vegetable itself retained 13 per cent of the original vitamin C and an additional 3 per cent was in the cooking water.[61]

In a study comparing retentions of ascorbic acid in canned peas with that in the same lot which was frozen, it was found that 8 varieties retained an average of 58.4 per cent of the original vitamin after 6 months of frozen storage. The average retention in similar canned peas at the end of the same period was 47.4 per cent, but, if the canning liquid was included, this rose to an average retention of 79 per cent.[62]

Losses vary with the vegetable. A similar study of canned and frozen green beans showed retentions of about one-third of the ascorbic acid in the cooked frozen product which had been held 10 months, and only about half as much in heated canned beans stored the same length of time. The amount of the vitamin in the cooking water was not determined.[63]

Frozen fruits usually retain a larger percentage of their original ascorbic acid than frozen vegetables. They are acid in reaction, a protective factor, and are not blanched. Probably on the average, frozen concentrated citrus juices approximate their fresh counterparts when reconstituted, but recent analyses of commercial samples show a very wide range in potencies. Frozen whole fruits decrease in vitamin C value if allowed to stand after thawing, but frozen concentrated citrus juices retain their potency to a high degree when reconstituted and held in a refrigerator 2 or 3 days, presumably because they are highly acid and have been deaerated.

Blanching of vegetables produces but little loss of vitamin A and greatly reduces losses during holding in frozen storage, presumably because destructives enzymes are destroyed. In general, losses of soluble minerals and vitamins of the B complex take place during blanching, but there is little change in these nutrients during frozen storage. Because the time required for cooking frozen vegetables is less than for the fresh, the final product will often be of about the same value.

[61] Van Duyne et al., *Proc. Inst. Food Technol.*, 1945, p. 13.

[62] Mahoney et al., *Ind. Eng. Chem.*, 38: 654 (1946).

[63] Dawson et al., *J. Home Econ.*, 41: 572 (1949).

In general, considerations of relative nutritive quality in deciding among the fresh, frozen, and canned forms of most fruits and vegetables at the market are probably not very important. We have seen that fresh products have a wide range in nutritive value from one variety to another and may have undergone considerable loss of vitamin C, in particular, since harvest. The method of preparation in the household is such a big factor in relation to actual nutrients consumed that it may offset variations caused by previous processing. It should be remembered that frozen and canned fruits have their original nutrients considerably diluted with sugar, as much as 50 calories or more in a serving.

Digestibility of Frozen Fruits and Vegetables

So far as digestibility is concerned, frozen fruits and vegetables resemble their fresh counterparts and freezing probably makes no significant change.

Sanitary Quality of Frozen Fruits and Vegetables

The wholesomeness of frozen fruits and vegetables has been the subject of much investigation. When such foods as spinach, strawberries, and raspberries are stored at temperatures of 22 degrees F. (−5.6 degrees C.) and lower, the number of microorganisms is small and tends to decrease during storage. They probably play no part in any of the changes taking place in the foods.

The most common types of microorganisms found in commercially frozen fruits and vegetables are ordinary soil forms which are not pathogenic but which cause spoilage of food not used promptly after defrosting. Among these soil organisms, however, the dangerous *Clostridium botulinum* may occasionally be present. Furthermore, its spores have been shown to survive temperatures as low as −40 degrees F. (−40 degrees C.) for several weeks, and higher freezing temperatures for a longer period. No toxin forms at freezing temperatures, but it occasionally develops in nonacid foods stored at 50 degrees F. (10 degrees C.), and at room temperatures it can be readily produced. Frozen fruits and vegetables are not known to have caused a case of botulism, however, and, if they are used promptly after thawing, there is no reason why they should.[64]

Other pathogenic organisms occur in frozen fruits and vegetables as a result of human or animal contamination or of contaminated

[64] Prescott and Tanner, *Food Res.*, 3: 189 (1938). Also Tanner et al., *Food Res.*, 5: 323 (1940).

water used during processing. Typhoid bacteria are 99 per cent killed in the original freezing, and frozen storage for 3 to 5 weeks kills most of the rest. Hence, it is not surprising that an outbreak of the disease has never been traced to these products. The rather common food-poisoning organisms of the *Salmonellae* group do not grow but fall off in numbers in foods stored at 41 degrees F. (4.4 degrees C.) or less. Therefore, properly handled frozen fruits and vegetables would never be responsible for such infection. Food-poisoning strains of *Staphylococci* which develop rapidly at room temperature but fail to multiply and produce toxin at 40 degrees F. (4.4 degrees C.) have been found in frozen vegetables.[65] Again, the possibility of poisoning is not a hazard under recommended conditions of use. Other microorganisms surviving the storage period also multiply rapidly after thawing, and spoilage occurs in a relatively short time as compared with sound live tissues. In conclusion, the general agreement that frozen foods should be cooked or eaten promptly when thawing takes place is based on considerations not only of maintaining the highest degree of palatability and nutritive quality but also of safety.

Palatability of Frozen Fruits and Vegetables

In general, it is the superior flavor, color, and texture of many fruits and vegetables, when frozen rather than canned, which furnishes the basis for prediction that this form of processing will be employed even more extensively than in the past. When fruits and vegetables of suitable varieties are harvested at the proper stage of maturity, handled carefully, properly blanched in the case of vegetables, frozen promptly at the proper rate, and held at a satisfactorily low and uniform temperature until prepared for the table, they may resemble closely the freshly harvested product in palatability. This means they are often superior to similar products which have been marketed in the fresh state. Home freezing also often results in products which are superior to home canned in palatability.

Preservation by freezing offers the possibility of wide distribution of fruits and vegetables at the peak of their eating quality. Regions especially adapted to growing a particular product can specialize and get it to the consumer with little loss of palatability. In general, the lower the storage temperature, and it should never be above

[65] Jones and Lochhead, *Food Res.*, 4: 203 (1939).

0 degree F. (-17.7 degrees C.), the longer will the original quality of the product be maintained. The best products may be ruined in cooking; short time, minimum water, and prompt serving are most important for retention of color and flavor.

Frozen fruits have the best flavor when they are still icy, and in any event should be eaten as soon as thawed, or texture and flavor deteriorate. Thawing in the package is desirable to protect the fruit from the action of air. When thawed fruit is left over, brief heating prevents further loss of eating quality.

Frozen concentrated citrus juices are rapidly displacing much of the fresh fruit, especially on northern markets. They compare favorably with the fresh product in every respect—nutritive quality and economy as well as palatability. The great saving in shipping costs makes it possible to price them on a basis highly competitive with the fresh. Other juices, including tomato and grape, are reaching the market in this form. No doubt the number will be increased, but, unless fortification with vitamin C to the citrus-juice level is employed, they should be utilized primarily for their refreshing and appetizing qualities.

Federal standards for grading frozen fruits and vegetables in retail size packages are being developed. In general, since it costs so nearly the same to produce and market low-grade as high-grade products, supplies will probably consist mostly of higher-grade products, which puts them in the luxury class of foods.

Economy of Frozen Fruits and Vegetables

To determine their relative economy, frozen fruits and vegetables may be compared with their fresh or canned equivalents in ready-to-eat form. In retail-size packages, the cost per serving is often several times that of the canned or in-season fresh product. This is not true of frozen products in large institutional size packages, which may be as cheap as the fresh. There is no waste in frozen products, and the labor involved in preparation of frozen foods is usually small compared with fresh, and in part offsets any added money costs.

As a method of home preservation, freezing is more economical in time and requires less equipment than canning, if commercial locker storage is available. However, if a household freezer is required, the interest on investment, depreciation, and cost of operation make freezing costs per unit of food 4 or 5 times that of canning.

In general, the use of freezing for home preservation as well as the purchase of frozen foods must rest largely upon the superior appetite appeal of frozen foods.

SELECTION AND USE OF CANNED FRUITS AND VEGETABLES

Although canning is one of the most effective methods of preserving fruits and vegetables, changes may take place during storage. Partial inactivation of ascorbic acid, thiamine, and, in some foods, of carotene, occur; color and flavor may deteriorate, and surviving microorganisms may multiply sufficiently to produce spoilage. All these changes are accelerated at higher temperatures.[66] At about 70 degrees F. (21 degrees C.), which probably represents average storage conditions, ascorbic acid retentions at the end of 1 year average about 75 to 90 per cent. Average retentions of vitamin A value are considerably higher.[67] Storage at no higher than 50 degrees F. (10 degrees C.) is desirable.

In general, each season's pack should be consumed within the year, and the lower the storage temperature the better, provided freezing does not occur. Actually, freezing does not make canned food unwholesome, but it may cause leaks which result in spoilage and softening of the tissues in some products.[68]

Appraisal of Canned Fruits and Vegetables

Nutritive Quality of Canned Fruits and Vegetables

Canned fruits and vegetables, like those which have been freshly cooked, undergo losses by solution and by inactivation. The same nutrients are affected, though to different degrees. In canning also, solution losses tend to be larger than those by inactivation. In fact, solution losses in canned vegetables tend to exceed those in freshly cooked products because the canned ones are oversoftened by the time-temperature combination required for preservation. Blanching adds to solution losses, but these can be conserved if the blanching water is used to fill the can. Losses by inactivation in canning

[66] Brenner et al., *Food Technol.*, 2: 207 (1948).

[67] Feaster et al., *Food Res.*, 14: 25 (1949).

[68] Smith and Smith, *Food Res.*, 9: 66 (1944).

involve not only those caused by blanching and processing but those which occur during holding in the can and during reheating for use.

If the canning liquids are consumed, total losses, except for thiamine, in canned vegetables may be less than those in freshly cooked products because the air is removed by exhausting the can before processing. The time and temperatures required for processing nonacid canned vegetables in particular result in more inactivation of thiamine than ordinary cooking. Canned citrus fruits and tomatoes have been known to retain their vitamin C very well. Much research has been directed toward improving commercial canning methods of other products to increase retention of vitamins. Sweet corn and green peas, relatively nonacid foods, when canned now also retain a high proportion of the original amount of vitamin C.

In using canned vegetables, conservation of nutrients in the canning liquid is particularly important because the overcooking necessary during processing causes larger solution losses than ordinary cooking. The liquid in the can tends to have about the same concentration of soluble nutrients as the solid portion. For the distribution of ascorbic acid between solids and liquids in canned peas, see Table XXVI. Discarding the liquid wastes 41 per cent of this

Table XXVI. Distribution of vitamin C in canned peas

[Richardson and Mayfield, *Mont. Agr. Expt. Sta. Bull.* 381 (1940)]

	Commercial canned peas	Home-canned peas
Mg. ascorbic acid in solid portion	43	73
Mg. ascorbic acid in liquid portion	30	51
Total mg. ascorbic acid in can	73	125
Proportion of ascorbic acid in liquid (per cent)	41	41
Proportion of ascorbic acid in solids (per cent)	59	59

vitamin as well as large percentages of other water-soluble vitamins and minerals.

In an investigation of the effects of concentrating the liquid from a number of canned vegetables to one-quarter to one-third of its original volume, followed by briefly heating the solids in the concentrated liquid, it was found that final retentions of ascorbic acid were 15 to 30 per cent better than when the liquid was discarded. Final retentions of riboflavin and thiamine averaged much higher

because there was little loss of these vitamins by inactivation. The same would be true for minerals which suffer no inactivation.[69]

The best sources of vitamin C among commonly eaten commercially canned fruits and vegetables are orange juice, grapefruit juice, grapefruit segments, tomatoes and tomato juice, asparagus, and spinach. The best sources of vitamin A among these foods are carrots, spinach, squash, apricots, and sweet potatoes.

The number and types of canned fruit and vegetable juices on the market is so large and consumers are so much influenced by flavor preferences that they deserve special attention in this discussion of nutritive quality. As we have emphasized previously, the principal nutritional roles of fruits and vegetables are the provision of vitamins A and C. Selection of juices should be primarily for vitamin C unless one is certain that it is otherwise provided for in the day's meals.

The extent to which nutritive quality of canned juices and related products approximates that of the corresponding whole fresh fruit or vegetable depends, of course, upon the portions included as well as upon the effect of the canning process. Properly labeled juices include no added water but consist exclusively of juice or juice and finely divided pulp. The cocktails and nectars are usually mixtures of juices and pulps with water and, in some cases, sugar or seasonings. "Fruit-drinks" may be artificially flavored and contain none of the natural fruit. The citrus juices closely approximate the whole fruit as ordinarily eaten because the concentration of soluble nutrients in the juice approximates that in the pulp. Canned tomato juice contains the entire fruit except skin and seeds.

Reduction of vitamin C potency during the canning of juices is caused by slicing, pulping, stirring in the sugar, and failing to exhaust the container completely. The last is sometimes responsible for inferior retention of the vitamin in glass as compared with tin. The reducing action of tin also protects vitamin C from inactivation so that products canned in tin tend to have higher potencies than those in glass.[70]

Since the principal nutritional function of fruits is to furnish vitamin C, it is legitimate to appraise the juices on the basis of content of this vitamin. See Table I for *Recommended Allowance* for an average man. If lemon juice is excluded because its high acidity

[69] Hinman et al., *J. Am. Dietet. Assoc.*, 21: 7 (1945).

[70] Hauck, *J. Home Econ.*, 35: 295 (1943). Also Moore et al., *Fruit Prod. J. and Am. Food Mfr.*, 23: 270 (1944).

limits the amount consumed at one time, only four commonly available canned juices contain enough vitamin C to be economical and reliable sources in amounts which are agreeable to consume: orange, grapefruit, tomato, and tangerine. Other canned juices should not be purchased unless the supply of vitamin C in the diet is known to be adequate or the label states that they are fortified with an amount of ascorbic acid that makes them at least equivalent to tomato juice (about 20 milligrams per 100 grams of juice). Apple juice, cranberry juice, and grape juice, fortified at the rate of 50 milligrams of ascorbic acid per 100 grams of juice at the time of canning, will have 35 milligrams, about the amount in canned grapefruit juice, when used.[71] Commercial vegetable and tomato juice cocktails contain half or less of the vitamin C value of tomato juice.[72]

Consumers should read labels of all canned juices and related products before buying. A number of synthetic fruit drinks are appearing on the market which might easily be mistaken for the natural product. Although the label may state that ascorbic acid is added, this information is insignificant without a statement of potency.

Canned juices, except fortified apple juice, are relatively stable when opened and may be held in a refrigerator for two or three days without significant loss of vitamin C.[73]

Altogether, canning is such an adequate method of conserving the nutritive value of foods that animals have been nourished on canned foods exclusively through several generations. There is no reason to believe that the same success could not be obtained with humans.

Digestibility of Canned Fruits and Vegetables

Canned vegetables in particular are so thoroughly cooked in processing that they are probably somewhat more completely digested than the cooked fresh product. Puréed types are available for infants or invalids who need to eat fibrous products in finely divided form.

The Sanitary Quality of Canned Fruits and Vegetables

The pathogenic organism of most importance in canned fruits and vegetables is the dangerous *Clostridium botulinum*, discussed previ-

[71] Esselen et al., *Food Prod. J. and Am. Food Mfr.*, 26: 11 (1946).

[72] Council on Foods and Nutrition, *J. Am. Med. Assoc.*, 121: 258 (1943).

[73] Scoular and Willard, *J. Am. Dietet. Assoc.*, 20: 223 (1944). Also Branion and Cameron, *Can. J. Public Health*, 38: 283 (1947).

ously in Chapter 3. If spores of this bacterium survive the processing, they may germinate and produce a toxin. This toxin is so deadly that one should never take the risk involved in tasting water-bath or oven-processed foods of the nonacid type such as string beans, peas, asparagus, and corn, to test their edibility. Modern commercial canned food is so carefully processed that outbreaks of botulism caused by these products have not occurred since 1925. Since that year almost all deaths from this cause have resulted from household-canned vegetables processed in a water bath. For this reason, in 1929, the United States Department of Agriculture issued a warning and a declaration that it no longer recommended any other than pressure-cooker processing for household canning of all nonacid fruits and vegetables. Even when a pressure cooker is employed for processing, safety is ensured only if it is properly exhausted before closing the petcock and if a sufficiently high pressure is maintained for an adequate period.

In tin cans, bulging ends may be signs of spoilage. Such products should be discarded without tasting. In either glass or tin containers, absence of a vacuum, as indicated by lack of inrush of air when the container is opened, is usually a sign of spoilage. More specific signs of spoilage of the botulinum type are:

1. Gas bubbles in the jars, tops of jars blown, spurt of liquid as cover is released.
2. Odor somewhat resembling rancid cheese.
3. Mushy or disintegrated appearance of all the solid parts of the contents of the can.

Slight evidence of any one of these signs of spoilage should lead to condemnation with no attempt at salvage. The toxin is destroyed by ten minutes of boiling, but all doubtful jars should be discarded. If the processing of nonacid vegetables has been of questionable adequacy, they should be actively boiled before consumption; the toxin may be present when there is no perceptible sign of deterioration.

There is a widespread belief that it is unsafe to permit canned foods to remain in the tins after they are opened. According to the editor of the *Journal of the American Medical Association*, however, "Canned foods, when allowed to remain in the can for several hours, will not cause symptoms of food poisoning unless they are

subsequently contaminated or previously toxic."[74] On the other hand, as was indicated in Chapter 3, foods may dissolve tin in the presence of oxygen, and iron if the latter is exposed. Tin salts have not been shown to be harmful, but iron salts affect flavor. For this reason, one may prefer to remove acid foods that are to be held overnight or longer before use, from the cans and transfer them to glass or enameled containers.

The belief that canned goods are unwholesome has persisted in some quarters from the time when their quality was questionable because scientific methods of production were less adequately understood than they are today. Canned foods of the type available on the market today or those produced in the household by proper methods meet high standards of sanitary quality more consistently than any other form.

Palatability of Canned Fruits and Vegetables

The problem of securing palatability in canned fruits and vegetables differs from the problem involved in ordinary cooking because it is complicated (1) by the heating in a closed container when the food is processed in the can, (2) by the time of heating necessary to obtain a satisfactory degree of sterilization, and (3) by chemical changes that may take place during storage. These will be discussed below in connection with the palatability factor involved.

Flavor. The flavor of canned fruits and vegetables depends upon what happens to the product between the field and the can, as well as upon what takes place in the can itself. The importance of harvesting these foods at a proper stage of maturity, and of quick handling combined with proper storage conditions before cooking or packing in jars, has been explained in previous pages. The pea canners have a slogan that recognizes the importance of such considerations in the statement that there should be but "1 hour from field to can." Quick cooling after processing and low temperature storage of the cans helps to preserve fresh flavors.

Vegetables suffer a disadvantage in ordinary canning in that they are packed in water, which dissolves many of the flavoring substances. Even if the liquid is utilized, as it should be to conserve its mineral and vitamin content, the vegetable tissue itself has lost flavor. A

[74] Anon., *J. Am. Med. Assoc.*, 90: 459 (1928). See also answer to inquiry, *J. Am. Med. Assoc.*, 107: 1582 (1936).

commercial method of canning which remedies this difficulty is now being used for corn and peas. It consists of packing these vegetables in cans which are exhausted without the addition of water, sealed, and then processed in the steam formed from their own moisture. Not only do such products have a superior flavor, but the cans are lighter in weight and more economical to transport.

The use of sugar and the consumption of the juice add to the desirability of the flavor of canned fruits. Although there is some change, owing to the application of heat, frequently the commercially canned product is superior to the fresh when the latter has been picked in an immature state for long-distance transportation. Most people would agree that commercially canned apricots have more flavor than the fresh fruit available in our northern markets, for example. Adding ascorbic acid in canning fruits improves the flavor of some.

The flavor of canned juices can be improved by restoring air which has been removed in canning. An easy way to do this is to pour the juice several times from one container to another just before it is to be consumed.

Color. The anthocyanins and chlorophyll usually suffer undesirable changes during canning. Anthocyanins as found in grapes, apples, plums, raspberries, strawberries, and blackberries give different shades of pink, violet, and purple during processing in tin, owing to the formation of metallic compounds from the pigment and the tin. Enameling the inner surface of the tin helps to prevent this discoloration, but there are always small areas of exposed tin along the seams which are open to the combined attack of all the chemical action of the pigment. This not only damages the color but frequently causes perforations of the can, thus adding to the economic losses in the industry. Acid fruits are easiest to handle because the acid depresses these reactions. When processing is carried on in glass, the original color is preserved, except for a lessening in intensity owing to partial conversion of the pigment into colorless forms by the heat.

The effect of canning on chlorophyll is well illustrated by spinach. In all cases, the canned material changes to the characteristic olive-green or brownish-green color of any green vegetable cooked a long time in a covered vessel. It is, of course, necessary that the processing take place in a closed container, and the time be prolonged,

compared with that of cooking for immediate consumption, to secure the essential degree of sterilization. The same difficulty in securing an attractively colored product constitutes a problem in the production of canned peas and green beans. A commercially successful method of retaining the original color of canned peas depends upon addition of sodium carbonate to reduce acidity and hence retard the change of chlorophyll to phaeophytin. Further addition of a little magnesium hydroxide tends to prevent the color change during storage. These substances are harmless, but must be indicated on the label.[75] Non-enzymatic browning may develop in some canned fruits, particularly in peaches above the liquid line in glass jars. It can be prevented by the addition of ascorbic acid.

Canning in tin results in other types of problems relating to color. The sulfur in corn and certain other products may unite with iron from the container to form black iron sulfide, a harmless product but one that is very objectionable in appearance. The use of tins lined with an enamel containing zinc has largely solved this difficulty because zinc sulfide is white. Quick cooling at the end of the process helps to diminish the difficulty. Tin cans are superior to glass for canning foods which present this problem because they may be plunged into a cool bath for very rapid cooling.

Texture. Many canned fruits and vegetables inevitably have an overcooked texture on account of the amount of heating required to make them keep. The problem of canning well-ripened tomatoes so that they will retain their shape when taken from the can has been solved by placing the fruit in calcium chloride solution before canning or by adding calcium chloride to the can.[76] The firming action has been shown to be caused by the production of calcium pectate.[77] The amount of calcium in some hard waters is sufficient, however, to have too much hardening action in the canning of beans and peas. The difficulty is avoided by using water softeners.

Grading Canned Fruits and Vegetables. Federal grades are available on a voluntary basis for use with canned fruits and vegetables but are indicated on labels only to a limited extent. Grades are based on such qualities as freedom from defects, uniformity in size, degree of maturity, and tenderness.

[75] Blair and Ayres, *Ind. Eng. Chem.*, 35: 85 (1943).

[76] Kertesz et al., *N. Y. State Agr. Expt. Sta. Tech. Bull.* 252 (1940).

[77] Loconti and Kertesz, *Food Res.*, 6: 499 (1941).

In general, Grade A represents the best quality, consisting of carefully selected products; Grade B is a general utility grade satisfactory for most uses; Grade C is wholesome and nutritious food but lowest of the three in palatability qualities. It may be quite acceptable for many uses, especially in food mixtures.

Provision is also made for selling products which are below Grade C in quality, though entirely wholesome. These must always carry the designation, "Below Standard in Quality."

When the prefix "U. S." appears before the grade designation on a label, the product has been under continuous inspection of the United States Department of Agriculture during canning and may also bear the label statement, "Packed under the Continuous Inspection of the U.S.D.A." Although products bearing the letter designation alone are expected to conform to the grade standards, those which have been inspected during processing are more likely to be uniformly of the quality indicated.

Surveys show that most canners do not grade the fresh product but pack "field run" quality and sell it all under one brand label. Hence price is not a good guide to quality of these foods.[78]

Economy of Canned Fruits and Vegetables

Canning is important to help us to secure well-balanced menus economically. If it were not for commercial and home canning of fruits and vegetables, even with our present system of transportation and the seasonal gradation of supply corresponding to geographic variation in climate in the producing regions, these foods would be unavailable to many people during a large portion of the year because of their high prices. The price of commercially canned products is influenced by such factors as the size of the pack, the carryover, consumer purchasing power at the time, imports of fresh and canned goods, competing fresh products, amount of household canning, competition of other canned products, and the price level of all canned products as a group. Often commercially canned products can compete successfully with the fresh, even in seasons of relative abundance. Differences in grade make it difficult to compare directly the cost of fresh and canned goods as they reach the consumer, but it is frequently cheaper to buy the canned rather than the fresh, and canned are almost always cheaper than frozen. In a

[78] Burdettie et al., *Md. Agr. Expt. Sta. Bull.* A23 (1943).

nationwide survey of comparative costs of 12 commonly used fruits and vegetables in retail-size containers or lots, it was found that canned products were both the most generally available and the cheapest. It was estimated that frozen foods averaged approximately 50 per cent higher in cost than canned. Another advantage of canned is their relative uniformity in price throughout the year.[79]

When they are so designated, Grade C canned products usually offer the best buy in nutritive value. Canned spinach is usually the best buy for vitamin A value, and canned grapefruit or orange juice for vitamin C.

Costs of household canning include (1) cost of raw food whether raised or purchased, (2) costs of jars, cans, rubbers, fuel, and depreciation on equipment such as a pressure cooker, (3) cost of labor, and (4) costs resulting from losses in storage. Farm families, of course, do the most canning but the BHNHE has found that many city families do some home canning—over 60 per cent of those in the small cities and 20 per cent of those in the larger cities.[80] Although home freezing is gaining in popularity among these families, canning continues to be practiced to a much larger extent, presumably because of its lower cost.

In planning for home canning it is worth while to consider which products offer the greatest nutritive values and money savings in comparison with the usual cost of commercial equivalents. Use of proper methods, including a pressure cooker for nonacid foods and cool storage, cuts losses to a negligible minimum. In one study of spoilage in home-canned foods it was estimated that about three-fourths was caused by understerilization and one-fourth by improper sealing.[81] Families that can raise their own food are much more likely to have good diets throughout the year if they have an extensive program of home food preservation.

The problem of buying canned fruits and vegetables efficiently is complicated by the absence of standardization of can sizes and the impossibility of judging proportions of solids from weight, the common units of measure indicated on the label except in the case of juices. Can sizes that are used most frequently are as tabulated.

[79] Krehl and Cowgill, *J. Am. Dietet. Assoc.*, 24: 304 (1948); 26: 168 (1950).

[80] "Home Food Preservation by City Families, 1947," *U. S. Dept. Agr., Preliminary Rept.* 15 (1950).

[81] Fisher and Esselen, *Food Res.*, 10: 197 (1945).

Size	Approximate weight of contents	Approximate volume of contents	Approximate cupfuls
No. 1 tall	1 pound	15 fluid oz.	2
No. 303	1 pound		2
No. 2	1 pound, 4 oz.	1 pint, 2 fluid oz.	2¼
No. 2 cylinder	1 pound, 9 oz.	1 pint 7 fluid oz.	3
No. 2½	1 pound, 13 oz.	1 pint, 10 fluid oz.	3¼
No. 3 cylinder		1 pint, 14 fluid oz.	5¾

SELECTION AND USE OF DRIED FRUITS AND VEGETABLES

Dried fruits and vegetables include (1) naturally dry beans, peas, and nuts, and (2) process-dried fruits and vegetables. Process drying is employed because removing a proper proportion of the water from these foods preserves them by destroying part of the microorganisms which cause spoilage and by producing conditions which inhibit the development of those that are left. Drying also reduces the deterioration caused by self-contained enzymes. When properly dried, vegetables are crisp and brittle, usually containing not over 7 to 8 per cent of moisture. According to federal standards, dried fruits may not contain more than 24 to 26 per cent water because of danger of spoilage. Many market samples, however, are above the legal standard in water.

The first step in the preparation of dry fruits and vegetables is reconstitution of their water content. In the past, the most common household method of restoring water to dried fruits and dry beans has been soaking for 5 to 6 hours or overnight in cold water before cooking. However, dried fruits rehydrate just as adequately if covered with boiling water and allowed to soak 1 hour before cooking. Dry beans brought to a boil and boiled two minutes, then allowed to stand for 1 hour before continuing cooking are also satisfactory. In both types of products, maximum water absorption is promoted by slow heating to the boiling stage during cooking.[82] Most process-dried vegetables, such as julienne and cubed potatoes, onions, and cabbage, rehydrate adequately during cooking, but may be somewhat improved in palatability if subjected to 1 to 3 hours of preliminary soaking.[83] All dried fruits and vegetables should be

[82] Spinella et al., *J. Am. Dietet. Assoc.*, 21: 148 (1945).

[83] Stillman et al., *J. Home Econ.*, 36: 28 (1944).

cooked in the water used for soaking to conserve dissolved flavors and nutrients.

The Appraisal of Dried Fruits and Vegetables

The Nutritive Contributions of Dry Beans, Peas, and Nuts

Dry beans, peas, and nuts are classified together nutritionally because of their substantial contributions of protein. (See Table XXVII.) In general, a double serving (a little more than 1 cup) of cooked dry beans or peas equals, on the average, in protein value, 4 ounces of lean meat weighed before cooking. One-fourth cup of peanut butter is equal in protein value to an average serving of meat and surpasses meat in niacin.

The proteins of the legumes—beans, peas, and peanuts, especially those of soybeans and peanuts—resemble animal proteins in containing all essential amino acids. All are good sources of iron and the B complex, but long baking or canning of beans and roasting of peanuts greatly reduces their thiamine value.[84] The darker the roast, the greater is the loss of thiamine in peanuts, but it is impossible to obtain good flavor in peanut butter without large losses of thiamine.[85] Soybeans are so outstanding in their contributions and, in the form of flour, so easy to incorporate in other foods, that we might well learn to extend our use of them.[86]

The Nutritive Contributions of Process-dried Fruits and Vegetables

Although enzymes inactivate a considerable proportion of the carotenes in fruits during drying and storing, dried apricots and peaches remain good sources. A ½-cup serving containing approximately 12 halves of cooked dried apricots provides more than half of the *Recommended Allowance* for an average man. The same size portion of cooked dried peaches (5–6 halves) provides a little over one-fourth of the *Recommended Allowance*.[*] Except for dried sweet potatoes, losses of vitamin A value in dried vegetables are

[84] *Mass. Agr. Expt. Sta. Bull.* 417 (1944). Also Fournier et al., *Food Res.*, 14: 413 (1949).

[85] Pickett, *Ga. Agr. Expt. Sta. Circ.* 146 (1944).

[86] Cahill et al., *J. Nutrition*, 28: 209 (1944); McCay, *J. Home Econ.*, 39: 629 (1947); Vail and Smull, *J. Am. Dietet. Assoc.*, 21: 698 (1945).

[*] Watt and Merrill, *U. S. Dept. Agr. Hdbk.* 8 (1950).

Table XXVII. The nutritive contributions of dry beans, peas, and nuts, given as percentages of the *Recommended Allowances* for a physically active man

[Based on Babcock, N. J. Agr. Sta. Bull. 751 (1950)]

Food, description and measure	Food nutrients: Energy	Protein	Calcium	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Ascorbic acid
Red kidney, cooked or canned, ½ cup (128 gm.)	4	10½	5	20½	(0)	4	3½	6½	(0)
Navy or pea, baked with pork and molasses, ½ cup (130 gm.)	5½	11	7½	23	1	4½	2½	4	4½
Red kidney, raw, ¼ cup scant (50 grams)*	5½	16½	8	27	(0)	19	6	8	1
Navy, pea beans, raw, ¼ cup scant (50 gm.)	6	15	8	29	(0)	22	6½	7	1
Lentils, raw split, ½ cup scant (50 gm.)	6	17	2	31	6	19	7	7	3
Lima, mature, raw, ¼ cup approx. (50 gm.)	5½	15	3½	31	(0)	16	5	7	1
Soybeans, mature, raw, ¼ cup (50 gm.)	5½	25	11	33	1	36	8½	8	(0)
Soybean flower, low fat, ½ cup (50 gm.)	4	32	13	54	1	27	10	10	(0)
Peas, split, raw, ¼ cup (50 gm.)	6	17½	2	9	21	26	8	10	1
Peanuts, Virginia type, roasted, shelled, ⅜ cup (50 gm.)	9	19	4	8	(0)	10	3½	54	(0)
Peanut butter, 3 tablespoons (50 gm.)	19½	19	4	8	(0)	4	3½	54	(0)
Almonds, unblanched, ⅜ cup, approx. (50 gm.)	10	13	13	18	(0)	8	18½	15	(0)
Walnuts, English, ½ cup (50 gm.)	11	11	4	9	(0)	16	3½	4	2

* 50 grams (1.8 ounces) of dry beans or peas make from ½ to ¾ cup cooked.

likely to progress rapidly during storage, leaving them unreliable and in most cases insignificant sources.[87]

Losses of ascorbic acid in drying and holding fruits and vegetables are usually so large that by the time they are stored and cooked they are poor sources. In some cases, the loss is partly a result of solution in blanching, but also of inactivation. In a study comparing carotene and ascorbic acid retentions in 8 varieties of peas, which were frozen, canned, and dehydrated, stored 6 months and then cooked, it was found that carotene values of the frozen and canned averaged about two-thirds of the fresh, whereas that of the dehydrated was about one-half of the original. In the same products, ascorbic acid retention averaged a little over one-half for the frozen and canned and about one-fifth for the dehydrated.[88]

Treatment of dried fruits and vegetables with sulfur dioxide during drying is highly destructive to thiamine, but fruits are not important sources of this vitamin anyway.

Besides the vitamin losses mentioned, blanching causes additional solution losses of other vitamins and minerals. Other nutrients such as protein and carbohydrate are almost entirely retained. Home drying and storing technics are likely to produce higher losses than commercial.[89] However, it has been found possible to build balanced meals entirely from dried foods when a dehydrated citrus juice was used as a source of vitamin C.[90]

Digestibility of Dried Fruits and Vegetables

The protein of dry beans and peas is more completely digested when they are cooked. Grinding produces the same effect in soybeans. Baked beans tend to remain in the stomach longer than other vegetables, probably on account of their relatively high protein content. Discomfort from gas formation after eating dry beans, and sometimes fresh peas and corn, is probably a result of intestinal fermentation of the hemicelluloses in the tough skins, but, in beans, it may also be caused by the nature of the starch. Bean starch is particularly resistant to digestive enzymes even after long cooking.[91] Process-dried fruits and vegetables appear to be as

[87] Tressler et al., *Am. J. Public Health*, 33: 975 (1943).

[88] Mahoney et al., *Ind. Eng. Chem.*, 38: 654 (1946).

[89] Batchelder, *Am. J. Public Health*, 33: 941 (1943).

[90] Deuel and Johnson, *J. Nutrition*, 34: 507 (1947).

[91] Bowman, *Food Res.*, 11: 49 (1946).

completely digested as the fresh products.[92] However, if dried fruits are eaten without cooking they should be well chewed. A number of cases of intestinal obstruction have resulted from swallowing large pieces which rehydrated in the alimentary tract.

Sanitary Quality of Dried Fruits and Vegetables

The sanitary quality of dried fruits and vegetables depends upon the nature of the processes used and the care employed during drying and marketing to exclude such sources of contamination as flies and other insects, rodents, and filth. Dehydrated products are superior to sun-dried in sanitary quality because of the higher temperatures used and the reduced chances of contamination. Fruits which are commonly sun-dried and eaten without cooking, such as dates, black figs, and seedless and cluster raisins, should be pasteurized, though this is not always done at present. Methods of pasteurization which promote keeping and guarantee wholesomeness without affecting palatability are being increasingly used, however. Lye dipping, as practiced with prunes, undoubtedly kills many surface microorganisms, and sulfuring has a distinct antiseptic action. The natural acidity of most dried fruits also retards the growth of most pathogenic microorganisms. Dried vegetables of both the natural (beans and peas) and process-dried types are cooked before eating so that the hazard resulting from contamination with pathogenic organisms before cooking is slight.

Commercial shelled nut meats have been studied for evidence of contamination. Although nuts in the unbroken shell do not contain bacteria of the type indicating contamination with human excreta, a large proportion of the shelled samples whether in glass, tin, or other packages, contain them. The contamination is a result of manipulation by human hands in shelling. These products should also be pasteurized.

The practice of sulfuring has been somewhat controversial from the standpoint of wholesomeness, but it has never been possible to demonstrate any damage to health from ingestion of sulfur dioxide, even when much larger amounts were taken than would be obtained in dried fruits. Although such negative evidence cannot be taken as conclusive, there seems at present to be no experimental basis for condemning the practice on grounds of unwholesomeness. Sulfur dioxide is converted to sulfates of a type common in body metabol-

92 Deuel and Johnson, *op. cit.*

ism and readily excreted. The amount consumed is much less than that in the fruit when first processed. In six months of storage about half of the sulfur dioxide evaporates and half of the remainder disappears in cooking. If sulfuring is to be eliminated, it will be necessary for the public to learn not to discriminate against a dark unpalatable-looking fruit, or for the industry to develop a more irreproachable method of conserving natural color. Blanching in steam or boiling water and dipping in acid or salt solutions are alternative processes.

Palatability of Dried Fruits and Vegetables

The principal problem sometimes appearing in the cooking of dry beans and peas is the slow rate at which they soften. By testing the rate of softening of dry beans which had been soaked over night in distilled water to which varying proportions of calcium chloride and sodium bicarbonate were added, it has been possible to show that this condition is associated with the hardness of the water. The beans soaked in calcium chloride solutions could be ranked in an increasing order of hardness which corresponded with increasing amounts of the salt. The sodium bicarbonate had the opposite effect, causing a more rapid development of the softness of texture associated with doneness. Others have found similar effects when baking soda was added to the water in which beans were either soaked or cooked. By this means, it is sometimes possible to halve the time required for cooking.

The proportion of soda recommended by different experimenters varies. The effectiveness of a given amount is probably related to the degree of hardness of the water, temperature of the water, time of soaking, etc. In Nebraska, it was found that 1/8 teaspoon of soda per pint of water was sufficient with all but one of several hard waters tested. One-fourth teaspoon was required for similar effect with the hardest sample of water. The method of testing included soaking for 5 hours at a temperature of approximately 120 degrees F. (48.9 degrees C.) and cooking in the soaking water. At the New Mexico Experiment Station, it was found that the effect of a hard water was counteracted and the time considerably shortened if beans were soaked for 10 to 14 hours in a solution of 1 1/2 teaspoons of soda to 5 cups of water. This was brought to the boiling point before the beans were added. The soaking water was removed and fresh water was added for cooking.

Experiments prove that the action of the soda is directly on the tissue rather than indirectly through softening of the water, because the soda solution is more potent than distilled water alone in accelerating cooking. The action of the soda, as noted previously, may be, at least in part, an increase in hydrolysis of hemicelluloses. In addition, soda forms soluble salts with pectic acid, whereas calcium and magnesium, the constituents of hard water responsible for slow cooking, are known to form insoluble salts with pectic acid. This action is believed to be especially significant in relation to softening. Acids, which precipitate pectic acid, also harden the skins. According to the Nebraska experimenter, "The pronounced effect of known pectic solvents on the bean seed coats is supported by the results of the chemical analysis, which show the presence of relatively large amounts of pectic acid or pectates in the bean seed coats. It would appear that the pectic materials bind the cellulose so densely that water is prevented from passing through the seed coats and from dispersing the cellulose sufficiently for tenderness." [93]

Molasses has a hardening action on beans, probably on account of its calcium content or acidity or both. Pure sodium chloride has no hardening effect on vegetables, but the small amounts of calcium chloride commonly added to table salt may have a noticeable action. The National Canners' Association reports that the toughening effect of hard water in canning is evident only with peas and shelled beans. The addition of soda to other vegetables during cooking to accelerate softening is likely to produce mushiness and is seldom practiced for that purpose, though this and other detrimental effects may result from its use to preserve greenness. In dry beans and peas, the absence of vitamin C eliminates concern over the effect of addition of soda to its potency, but the effect on thiamine may be adverse.

In general, the inferior palatability of dried fruits and vegetables, especially of process-dried vegetables, makes them unable to compete with fresh, frozen, or canned products. Process-dried vegetables are available on retail markets for the most part only in the form of dried soup mixtures, except for dried potatoes. Drying increases losses of volatile flavors and natural colors to a greater extent than canning or freezing. Losses in eating quality are more likely to progress during storage, especially if they are not stored at a very low temperature. Greens, peas, and corn, among a wide

[93] Snyder, *Nebr. Agr. Expt. Sta. Bull.*, 85 (1936).

variety of vegetables, have been reported to be the most palatable when dehydrated by household methods,[94] but others do not rate home-dried greens high.[95]

Economy of Dried Fruits and Vegetables

Dry beans and peas are the most economical source of protein among all our foods. On a per pound basis as purchased they contain somewhat more than lean meat. In servings of a little over 1-cup size, as stated previously, cooked dry beans and peas approximate an average serving of meat for this important nutrient. From the standpoint of economy, it is unfortunate that we do not readily accept soybeans either as a vegetable or in the form of flour to be incorporated in wheat flour mixtures, such as bread. A pound of dry beans or peas makes 8 to 10 half-cup servings.

Peanuts and peanut butter also outrank lean meat in protein on a weight basis, and at market prices are excellent buys. Other nuts are comparatively expensive, however. Waste in shelled nuts is given in Table XXVIII.

Table XXVIII. Refuse in market samples of nuts

(After Chatfield and Adams)

Nut	Per cent refuse	Nut	Per cent refuse
Almonds	49	Peanuts, Virginia style	28
Butternuts	86	Pecans	48
Chestnuts, dried	18	Walnuts (California, black)	78
Coconut	37.2	Walnuts (Persian or English)	55

Process-dried vegetables are not generally available because they have never become popular in this country. They would be economical because drying is an inexpensive method of preservation and their diminished bulk saves in transportation and storage costs.

Dried fruits are nearly always cheaper than equivalents preserved by canning or other processes, because less labor is required and the decreased weight and bulk diminish transportation costs. Furthermore, sugar is not added to the dried fruits. Except for prunes they have no preparation waste. Prunes are graded by size, according to number per pound. The proportion of pit to meat changes with the size of the prune, the general rule being the larger the

[94] Stillman et al., *J. Home Econ.*, 36: 28 (1944).

[95] Porter et al., *Food Res.*, 9: 268 (1944).

prune, the smaller the percentage of waste in pit. Although smaller prunes have a larger proportion of pit to meat, they are priced so much lower than the large that they are better buys. Dried fruits give about 10 servings per pound.

SELECTION AND USE OF FERMENTED AND SALTED FRUITS AND VEGETABLES

Fermentations are processes in which lactic acid, alcohol, and other products are formed from carbohydrate by certain appropriate kinds of microorganisms. The most popular fermented vegetable products are sauerkraut and cucumber pickles.

If vegetables or fruits are mixed with about one-fifth their weight of salt or placed in a strong brine, they keep for an extended period but do not ferment. Flavor is retained better if they are blanched first.[96] This method is especially adapted to leaves such as chard, spinach, and dandelion in which the sugar content may be too low for successful fermentation. The products must be freshened before use.

The Appraisal of Fermented and Salted Fruits and Vegetables

If fermented products are freshened or if the liquid is discarded, there are solution losses of water-soluble vitamins and minerals. Losses by inactivation have been investigated, particularly in relation to vitamins A and C. Since raw cabbage is an excellent source of vitamin C, the fate of ascorbic acid in kraut making is of special interest to the consumer.

In a study of the vitamin C potency of raw cabbage and kraut made from it, it was concluded that in commercial-size vats there was little loss so long as fermentation continued. During storage in the vats after fermentation the potency decreased, and the rate of loss was faster when storage was in smaller containers. In salted or brined vegetables which do not ferment and require freshening, little vitamin C and probably little of the other water-soluble nutrients are retained.[97]

Losses of vitamin A value appear to be somewhat less than those for vitamin C in fermented and salted vegetables, but in some salted

[96] Etchells and Jones, *U. S. Dept. Agr., Farmer's Bull.* 1932 (1943).

[97] Harris, *J. Am. Dietet. Assoc.*, 21: 360 (1945); Jones and Etchells, *Am. J. Public Health*, 34: 711 (1944).

vegetables they may run up to 90 per cent of the original values after 6 months' storage.[98]

Fermentation probably has no effect on the digestibility of fruits and vegetables. Sauerkraut juice is sometimes chosen for its laxative value.

Fermented and salted fruits and vegetables have not been the cause of any health problems. The lactic acid formed in fermentation is entirely wholesome and, in fact, usable by the body for energy.

The lactic acid-salt solution developed during fermentation acts upon the plant tissue to bring about characteristic changes in color, taste, and texture. Chlorophyll is partially destroyed during fermentation, probably in part at least by the acid. Salted products may retain their color well. Fermented products have a characteristic acid taste. Off-flavors are caused by the action of microorganisms other than the lactic acid bacteria. Salted products may retain more of their natural flavor than the fermented, but they often deteriorate after 6 months of holding. Sauerkraut and fermented pickles are the only fruits or vegetables preserved by either method which are widely consumed.

These methods are the cheapest ways of preserving the fruits and vegetables for which they are adequate, but high losses tend to increase costs in household manufacture and low demand reduces commercial production. Freezing and canning retain nutrients of importance more reliably, and the products are generally considered more palatable.

SUMMARY OF POINTS TO CONSIDER IN SELECTING AND USING FRUITS AND VEGETABLES

Fresh Fruits and Vegetables

1. Study the markets and follow price trends to take advantage of periods of low price.
2. See that you get full measure.
3. Buy first for vitamins C and A value.
   Best buys for C—usually grapefruit and oranges and cabbage.
   Best buys for A—usually greens, carrots, winter squash, and sweet potatoes.

[98] Harris, *op. cit.*

4. Examine quality below the top layer. Select quality according to price and use, but usually avoid wilted or partly decayed produce. Learn to recognize signs of good eating quality for each product.

5. Wash carefully or pare to remove germs and spray residues.

6. Serve raw often to conserve nutrients and roughage value. Slice or shred with a sharp knife rather than chop or grind for salads. Add salad dressings just before serving. Keep fresh juices in a refrigerator until served.

7. Eliminate or minimize solution losses because these may remove half or more of the essential minerals and water-soluble vitamins. To do this:

- (1) Employ waterless cooking, baking, or steaming as preferred because no added water is required. For steaming, a type of steamer which collects the condensed steam for consumption with the vegetable is preferred.
- (2) When water is added, use a minimum amount. If possible, time the evaporation of all the water that cannot conveniently be served with the vegetable to coincide with doneness. The rate of evaporation can be controlled by use or removal of the cover and by varying the intensity of the heat.
- (3) Save any surplus cooking liquids to serve in such forms as vegetable-juice cocktails, soups, sauces, and gravies.

8. Minimize the time of cooking because, other conditions being equal, this decreases losses by inactivation as well as by solution. To do this:

- (1) Have water hot when the vegetable is added.
- (2) If solution losses can be avoided, slice or shred the vegetable just before cooking to accelerate cooking.
- (3) Use a pan which heats evenly and efficiently. Generally such a pan has:
  - (*a*) A relatively large diameter in proportion to its height.
  - (*b*) A flat bottom to make uniform contact if the source of heat is other than an open flame.
  - (*c*) A bottom free from irregularities and level enough to facilitate even distribution of the water when the amount of liquid is low (prevents "hot spots" which cause sticking and scorching).
- (4) Cook with a cover.
- (5) Maintain brisk boiling; do not simmer or stew vegetables.
- (6) Halt cooking while the vegetable is still as crisp as is acceptable.

(7) If holding is unavoidable, cool and reheat rather than keep the product hot.

9. Do not add soda unless the amount is carefully measured.

Frozen Fruits and Vegetables

1. Compare values received for the price with those of fresh and canned.

2. Buy first for vitamin C and A value.
   Best buys for C—concentrated grapefruit and orange juices.
   Best buys for A—spinach, broccoli, winter squash.

3. Store at 0 degree F. (−18 degrees C.) or lower.

4. Serve frozen fruits as soon as thawed or when still slightly icy. Store reconstituted juices in the refrigerator for not more than 3 days. Thaw vegetables as the first stage in cooking or only partly thaw beforehand. Divide the package contents to get uniform cooking.

5. Follow directions for cooking fresh vegetables to reduce cooking time. Remember that frozen vegetables usually take only about half the time of the fresh.

Canned Fruits and Vegetables

1. Buy first for vitamins C and A value.
   Best buys for C—grapefruit and orange juices.
   Best buys for A—spinach, squash, sweet potatoes.

2. Buy the most economical size of can, provided the product can be used conveniently.

3. Select the grade suited to the use, remembering that price is not closely related to food value.

4. Store in as cool a place as is available without danger of freezing.

5. Aerate juices just before serving by pouring from one container to another.

6. Heat vegetables in the can liquid. Serve the liquid in some form.

Dried Fruits and Vegetables

1. Dried fruits are usually economical but they are not reliable sources of vitamin C. Dried apricots and peaches are good sources of vitamin A. Dry beans, peas, and peanut butter are relatively inexpensive sources of protein. Soybean flour when available is a good buy for protein and other nutrients except A and C.

2. For adequate reconstitution with water, add boiling water to dried fruits and soak 1 hour. Follow with slow cooking. Bring dry beans to a boil for 2 minutes, allow to stand for 1 hour, and then cook slowly. Cook dried fruits and vegetables in the soaking water, and serve it with the product.

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CHAPTER 10

MILK AND ITS PRODUCTS

MILK

Milk may be defined as the secretion of the mammary gland, and in different parts of the world may mean milk from cows, sheep, goats, or even camels or reindeer. However, in this country, milk generally designates cow's milk, and other milks used for human consumption are more specifically called goat's milk, human milk, etc.

The Structure and Composition of Milk

Milk from normal cows has the following average composition:

Water	87.0 per cent
Protein	3.5
Fat	3.9
Carbohydrate	4.9
Ash	0.7

The proportions of these components, especially of the fat, are variable and are affected by such factors as inheritance (breed and individual), stage of the lactation period, time of milking, season, and ration.

Milk proteins consist largely of casein and lactalbumin. The casein exists as a calcium compound and accounts for over 2.5 per cent of the whole weight of the milk. Lactalbumin comprises about 0.50 per cent, and the remainder of the protein is composed of several different proteins represented in much smaller proportions. Casein has been extensively studied because it is most abundant and because it is readily separated to form the principal component of cheese.

Milk fat contains a relatively high proportion of the lower fatty acids, especially butyric, and has a comparatively low melting point. These lower fatty acids smell strong and contribute the off-odors and flavors often associated with butter which has been held under conditions tending to cause hydrolysis.

The carbohydrate of milk is almost exclusively the sugar lactose. This is true at least for all land mammals. The proportions of sugar and protein in cow's milk are remarkably constant.

Besides the organic components just discussed, the solids of milk include the ash constituents—potassium, calcium, sodium, magnesium, iron, phosphorus, chlorine, sulfur, copper, zinc, aluminum, manganese, iodine, and traces of many others. With the exception of iodine, the mineral content of milk is apparently not significantly related to the food supply of the cow. When the cow's intake of bone-building minerals is inadequate, her body stores may be drawn upon to an extent that is physiologically harmful to her, and finally total milk production is reduced to maintain the normal level of the deficient mineral or minerals.

Other components of milk, minor in terms of amounts present, but important nutritively and in the use of milk in food preparation, are the vitamins and enzymes.

All the vitamins known to be essential to man are present in milk, but some of them vary markedly in quantity with the feed of the cow, and with some other factors. The supply of thiamine is relatively constant, because that derived from the feed is supplemented by digestion of the dead microorganisms which have developed in the animal's alimentary tract. The quantity is also unrelated to the breed of the cow or stage in lactation.

Although the riboflavin content of milk varies, milk from high-producing cows possessing a lower concentration, for example, it has been concluded that the proportion can be influenced only to a very limited extent by the ration. Milk is a relatively poor source of niacin, but it contains comparatively large amounts of the amino acid tryptophan, which is used in bacterial synthesis of this vitamin in the intestine.

One of the most variable nutritional properties of milk is its vitamin A potency. Cows may continue to secrete normal amounts of milk when they are so deficient in this vitamin that normal calving is interfered with, and under experimental conditions milk has been produced which was so low in this vitamin that nursing calves developed night blindness. The vitamin A potency of milk depends upon its content of both true vitamin A and carotenes. Breeds such as the Jersey and Guernsey, which give more highly colored milk, transfer a larger proportion of unchanged carotenes to their milk than do breeds such as the Holstein and Ayrshire, which produce less highly colored milk. The total vitamin A potency of milk is thus not necessarily related to color, and, on an equal butterfat basis, milks from all breeds tend to be similar in this factor when the cows have had similar feed.

Vitamins C and D are also present in varying and often unreliable quantities. Cows are able to synthesize ascorbic acid, but the amount present in milk as we use it is apparently much more affected by factors operating after it is drawn than by ration, breed, or stage in lactation. The amount of vitamin D in milk is primarily affected by the exposure of the cow to sunlight. Although the cow is able to transfer part of the vitamin D in the feed to her milk, ordinary rations contain only small amounts.

Of the many enzymes present in milk, those of major interest are phosphatase, the presence of which is used as a measure of adequate pasteurization, and peroxidase, lipase, and oleinase, which affect the flavor of milk and its products.

From the standpoint of structure, milk is very complex, containing substances in each of the three principal states of dispersion. The proteins are dispersed colloidally; the locations of individual particles of calcium caseinate are actually visible under the ultramicroscope as spots of light. Part of the calcium phosphates is also colloidally dispersed. Milk fat is present in the form of suspended, emulsified globules, ranging in size from 0.1 micron to 20 microns in diameter. It is estimated that there are more than 100 million fat

globules in one drop of average milk. Each globule is stabilized by a film of adsorbed protein and phosphatides which thus serve as the emulsifying agents. Substances in true solution in milk include the lactose, most of the mineral salts, and the water-soluble vitamins. Vitamins A and D are dissolved in the fat phase.

The Appraisal of Milk As a Food

Milk is the sole article of our diet the single natural function of which is to serve not merely as a food but as the entire diet of the young of all mammals. Consequently, as one would anticipate, it provides an especially well-balanced array of the essential nutrients, including vitamins, in a form that is palatable, digestible, and sanitary. Because cow's milk fulfills to a high degree these qualifications, even for man, it has been designated the "perfect food." Although a critical examination of its right to this title leads to qualification of the claim, milk comes nearer to deserving such recognition than any other food.

The Nutritive Quality of Milk

The relative nutritive contributions of milk are shown in Table XXIX. The calories that milk supplies make it much more than a mere beverage, but it takes up too much space to serve as the whole diet for average adults whose energy requirement of 2500 calories or more per day could be met only by consuming at least 3½ quarts.

The protein furnished by milk is not only important in quantity but well-balanced in its assortment of all essential amino acids. Milk fat is an excellent source of energy and contains the nutritionally essential fatty acids. However, its palatability and exaggerated ideas of its nutritional superiority have caused consumers to give it a monetary value out of proportion to its actual physiological importance. On account of its natural variability, the ease with which it can be removed, and the money value attached to it, the federal government and the states establish minimum percentages of fat, usually 3.25 per cent, for the product to be sold as whole milk. Products with less can be sold only as skim milk. Besides the minimum standard, a higher amount may be specified for Grade A milk.

It has been maintained that milk sugar is superior to other sugars, especially for infant feeding. This is attributed to its tendency to prevent intestinal putrefaction by encouraging the growth of acid-

Table XXIX. The nutritive contributions of milk and its products, given as percentages of the *Recommended Allowances* for a physically active man

[After Babcock, N. *J. Agr. Expt. Sta. Bull.* 751 (1950)]

Product	Measure *	Weight: Grams	Weight: Ounces	Food nutrients: Energy, %	Protein, %	Calcium, %	Iron, %	Vitamin A, %	Thiamine, %	Riboflavin, %	Niacin, %	Ascorbic acid, %
Whole milk †	1 cup	244	8.7	6	12	29	2	8	6	23	2	4
Skim milk or butter-milk	1 cup	246	8.8	3	12	30	2	(0)	6	24	2	4
Chocolate-flavored milk	1 cup	250	8.8	6	11	27	2	5	5	22	1	3
Evaporated milk	½ cup	126	4.5	6	12½	30½	1½	10	4	25½	1½	2
Condensed milk												
Sweetened	5 tbs.	100	3.5	10½	11½	27½	1½	(8½) ‡	3½	21½	1½	1½
Dry milk												
Whole	¼ cup	32	1.1	5	12	30½	1½	9	6½	26	1½	3
Skim	⅕ cup	24	0.9	3	12	31	1	0	6	26	2	2
Malted-milk beverage	⅔ cup	180	7.5	6	12	24	4	9	8	20	...	3
Cheese												
Cheddar	1½ in. cube	42	1.5	4½	12½	24	2	(9)	(1)	14	(0)	(0)
Cottage	3 tbs.	42	1.5	1½	12	4	1½	(0)	(1)	7½	(0)	(0)
Cream	6 tbs.	90	3.2	12	12	12	1	27	(1)	9	(0)	(0)
Cream												
Light (20%)	4 tbs.	60	2.1	4	2	6	(0)	10	1	5	(0)	(0)
Heavy (30%)	2 tbs.	30	1.1	3	1	2	(0)	9−	½	2	(0)	(0)
Ice cream	⅐ quart	81	2.9	5½	4½	10	1	8½	2	8½	½	1½
Sherbet	½ cup	96	3.4	4	2	5	0	0	1½	4	0	(0)

* Measures adjusted to give approximately equal amounts of protein except cream and ice cream.

† Pasteurized and raw.

‡ Imputed figures in parentheses.

forming bacteria there. It may also have a favorable effect on the absorption of calcium and phosphorus.

Among the mineral elements present are all those known to be necessary in human nutrition, though iodine may be very low in milk produced in some areas. The proportion of iron is also low, presumably because young mammals are ordinarily born with a liver supply to meet their needs until their diets are more diversified, but the iron which is present in milk is well utilized. Calcium and phosphorus, of which large amounts are needed by growing animals, are present in generous quantity. Milk is so outstanding in its supply of calcium that it is practically impossible to meet recommended standards for consumption of this mineral without including milk itself or its products in substantial amounts.

Important quantities of vitamin A are present in milk, although, as noted previously, considerable seasonal variation in vitamin A potency occurs that is related to the characteristic rations used. Although the range of values may be more extreme, in an outstanding dairying area winter milks were found to contain about half the vitamin A value of summer milks. Better winter-feeding practices are reducing this seasonal factor, however.

Milk is also a good source of thiamine and is relatively rich in riboflavin. The riboflavin in milk, however, is very sensitive to light. When milk in clear glass bottles is exposed to direct sunlight, it may lose half or more of its riboflavin in 2 hours.[1] Although milk is low in niacin, it still has high antipellagra value because of bacterial synthesis of niacin from tryptophan.

As it reaches the consumer, milk is an extremely variable and generally unreliable source of vitamin C. Pasteurization as ordinarily practiced reduces the vitamin C activity of milk, but this loss can be largely prevented by removal of dissolved oxygen and prevention of contamination with copper. Like riboflavin, vitamin C in milk is inactivated by light, and milk should be protected from this loss.[2]

With the exception of eggs, liver, and sea foods, milk and its products are our sole natural sources of vitamin D. Consequently, there has been extensive investigation of the antirachitic value of dairy products. Prevention of rickets requires adequate supplies

[1] Peterson et al., *J. Am. Chem. Soc.*, 66: 662 (1944). Also Ziegler, *J. Am. Chem. Soc.*, 66: 1039 (1944).

[2] Holmes and Jones, *J. Nutrition*, 29: 201 (1945).

of calcium and phosphorus as well as of vitamin D. Milk, as noted previously, is an outstanding source of these two minerals, but the amount of the antirachitic vitamin varies. As will be pointed out in the section on fortification of milk, milk that is a substantial source of vitamin D can be produced by feeding the cows materials such as cod-liver oil and irradiated yeast which are high in this vitamin, but the transfer to the milk is very inefficient. Under ordinary conditions, however, cow's milk does not contain nearly enough vitamin D to prevent rickets in babies.

Cow's milk is not a perfect food in the sense that it alone meets all requirements for a human being at any age. It can serve as the foundation of an infant's diet, but it requires modification and supplementation to perform this function well. Modification ordinarily includes dilution to bring the proportion of protein down to that found in human milk. This reduces the quantities of other components in a given volume. Calcium, riboflavin, and thiamine remain adequate in amount, but vitamins C and D should be supplemented by other potent sources, and extra calories are usually added in the form of a suitable sugar. See Table XXX for a comparison of the nutrients in human, goat, and cow milk.

Table XXX. Comparative average nutritive values of human, goat's, and cow's milk

[From Macy et al., *Bull. Natl. Research Council*, No. 119 (1950)]

	100 ml. milk		
Nutrient	Human	Goat	Cow
Energy, calories	71	78	69
Fat, grams	3.8	4.1	3.8
Lactose, grams	7.0	4.7	4.8
Protein, grams	1.2	3.4	3.3
Calcium, mg.	34	130	126
Iron, mg.	0.21	0.05	0.13
Vitamin A, mmg.	54		37
Carotenoids, mmg.	32		39
Thiamine, mmg.	15	48	42
Riboflavin, mmg.	46.9	114	158
Niacin, mmg.	172	273	85
Ascorbic acid, mg.	4.4	1.3	1.8

Deficiencies of milk appear if it is retained as the only food past normal weaning age. Young mammals of several species have been found to develop an anemia when restricted to a milk diet. This

condition can be prevented by giving additional copper and iron, but in practice these minerals should be provided by a properly diversified diet at an early age. As growth proceeds, the proportion of water in milk which makes it impossible for an older animal to consume enough to meet its energy requirement becomes a limiting factor in its adequacy.

In spite of these limitations, milk is the most nearly perfect food that we have, and it possesses high supplementary value in dietaries at all ages. Occasionally it is maintained that, because animals in the natural state do not consume milk for more than a limited period corresponding to infancy and early childhood, milk is unnecessary for human adults. Nature, however, unlike individual man is always primarily interested in numbers of offspring and welfare of the individual through the reproductive period, and not at all in individual welfare after the reproductive period. It is altogether possible that scientific nutrition will enable modern man to prolong the period of vigorous middle age and that of enjoyable old age far beyond that prevailing among primitive peoples. Animal experiments show that the specific nutrients giving evidence of added benefits with intakes above that required for a normal life cycle include vitamins A and riboflavin, and calcium. Milk contains all three and is the richest ordinary food source of the last two.

Furthermore, most other mammals are either provided with an alimentary tract which is able to handle large quantities of leafy foods, the best plant source of calcium, or they have the habit of eating the entire bodies of other animals and thus acquiring their stores of calcium. Man is equipped neither to digest large quantities of bulky plant foods nor to masticate bones.

One of the most marked and at the same time health-promoting changes in food habits in the United States during this century has been the increased consumption of milk and products which contain its major nutrients. (See Table XXXI.) But further increases are needed to bring average calcium intakes up to the level of the *Recommended Allowances.* The greatest problem is increasing consumption on the part of low-income groups and members of every income group who consume less than the recommended amounts. In 1948, city families were found to consume increasing amounts of milk per capita as income increased up to the \$7500 level.[3]

[3] "Food Consumption Surveys," *U. S. Dept. Agr., Prelim. Rept.* 12 (1949).

Table XXXI. Approximate per capita consumption of total milk equivalent [a] and major dairy products other than butter, 1918–1948

[From *U. S. Dept. Agr., Misc. Pub.* 691 (1949)]

Product	Year 1918	1928	1938	1948
Total milk equivalent	204 qt.	201 qt.	216 qt.	269 qt.
Fresh whole milk (1 qt. weighs 2.15 lb.)	288 lb.	271 lb.	265 lb.	302 lb.
Evaporated whole milk (1 lb. equals 2.02 lb. whole milk)	4.8 lb.	10.1 lb.	15.5 lb.	18.7 lb.
Dry whole milk (1 lb. equals 7.64 lb. whole milk)	....	0.1 lb.	0.1 lb.	0.3 lb.
Skim milk and buttermilk	85.5 lb.	73.7 lb.	75.2 lb.	67.5 lb.
Evaporated and condensed skim (1 lb. condensed equals 3 lb. original fluid)	1.8 lb.	2.6 lb.	3.0 lb.	4.8 lb.
Dry skim (1 lb. equals 9.83 lb. fluid)	....	0.8 lb.	2.1 lb.	3.1 lb.
Cheese, cottage (1 lb. equals 3.00 lb. milk)	0.6 lb.	1.2 lb.	1.6 lb.	2.8 lb.
Cheese, other than cottage (1 lb. equals 6.88 lb. milk)	3.8 lb.	4.4 lb.	5.8 lb.	6.8 lb.

[a] The milk equivalent included all milk products except butter and was based primarily on mineral and protein content.

However, at each income level, a larger proportion of families failed to get the *Recommended Allowance* for calcium than any other nutrient.[4]

Even wider than the range in consumption of milk among families, is the variation among individuals. In a survey of New York state tenth grade children, about half of the girls were found to consume 3 or more cups daily, but about one-fourth had less than a pint. The boys averaged a little higher, almost two-thirds having 3 or more cups and about one-sixth having less than a pint.[5] Adults made a poorer showing—a tenth of the pregnant women having less than ½ cup daily and only about one-fifth getting the quart or more that is recommended. Among homemakers one-fifth had less than ½ cup, and two-fifths of female industrial workers consumed this very low quantity.[6] Similar findings in other areas indicate that the increased average consumption of milk does not

[4] "Nutritive Content of City Diets," *U. S. Dept. Agr., Special Rept.* 2 (1950).

[5] Trulson et al., *J. Am. Dietet. Assoc.*, 25: 595 (1949).

[6] Trulson et al., *J. Am. Dietet. Assoc.*, 25: 669 (1949).

represent as favorable a situation as it might if it more nearly represented the entire population.[7]

Although average existing levels of milk consumption in the United States are below those believed to be optimum, in 1948, for example, the amount of milk and milk products consumed made important contributions of almost all nutrients. When butter, which furnishes little but energy and vitamin A, was excluded, dairy products provided 13.8 per cent of the food energy, 25 per cent of the protein, 76.0 per cent of the calcium, 3.5 per cent of the iron, 12.9 per cent of the vitamin A, 10.2 per cent of the thiamine, 47.1 per cent of the riboflavin, 3.6 per cent of the niacin, and 5.7 per cent of the ascorbic acid consumed.[8]

To meet the revised (1948) *Recommended Allowances*, especially for calcium, adults and children up to the age of 10 should have at least 1½ pints of milk per day, and older children, youths to the age of 20, and pregnant women, at least 1 quart. Women who are lactating should have as much as 1½ quarts. Except for the latter group, a maximum of 1½ quarts is probably as much as most individuals have room for if they get the other foods needed to balance milk. An exaggerated intake of any single food is neither advantageous nor advisable.

Fortification of Milk. In some instances, concern for particular nutritional inadequacies of milk, and in others the desire to exploit current popular interest in nutrition, have led to a variety of suggestions for "mineralization" and "vitaminization." Suggestions for mineralizations have been confined to iodine, copper, and iron. It is possible but not generally practiced to increase the iodine content of milk through the rations of the cow. Adding copper and iron directly to milk has been considered, but rejected, as being associated with too many practical hazards, increased vitamin inactivation, for example.

Special considerations apply to improvement of the natural vitamin A potency of milk at certain seasons and to reinforcing its vitamin D content. The difference between summer and winter milks in vitamin A potency is being narrowed by improved winter feeding, and is desirable because it is practical, not necessarily expensive, and may be of advantage to the cow and her offspring as well as to the human consumer.[9]

[7] Phipard, *Am. J. Public Health*, 41: 45 (1951).

[8] *U. S. Dept. Agr., Misc. Pub.* 691 (1949).

[9] Council on Foods and Nutrition, *J. Am. Med. Assoc.*, 128: 204 (1945).

Among the considerations leading to authoritative approval of reinforcing milk with added vitamin D is the fact that, in spite of the general availability of such effective sources of this vitamin as cod-liver oil and similar products, rickets has not been entirely eradicated, nor, because of ignorance and neglect, is it likely to be so as long as individual effort is responsible. No potent ordinary food sources of vitamin D exist. Supplementation of milk, the universal food at a critical stage, provides a simple and certain means of prevention. The Food and Nutrition Board of the National Research Council favors fortification of milk with vitamin D only.

Methods of augmenting the low natural vitamin D content of milk which are commercially successful include (1) feeding the cows vitamin D concentrates, such as cod-liver oil, irradiated yeast, or irradiated ergosterol, (2) ultraviolet irradiation of the milk, and (3) the addition of vitamin D concentrates directly to the milk. These have been called "metabolized," "irradiated," and "fortified" vitamin D milks, respectively.

When extremely high levels of vitamin D concentrates are fed to cows, the vitamin D potency of their milk may increase thirty times or more. It is practical to produce such a milk containing about 400 USP units of vitamin D per quart containing 4 per cent fat. The cost has been estimated to be ½ cent to 1 cent per quart. Metabolized vitamin D milk has the advantages of being a milk "naturally rich in vitamin D" and of having undergone no special treatment for this purpose after coming from the cow.

Irradiation by carbon arc lamps has been perfected so that it is possible and practicable to impart a potency of 400 USP units per quart of milk without injuring other vitamins or flavor. This is the cheapest method of supplementing milk in vitamin D content on a large scale. It is perhaps less subject than other methods to human errors.

The third method of supplementing the vitamin D content in milk, that of adding concentrates directly to the milk, is much more common. These concentrates are also commonly added in such quantities as to give a milk containing about 400 USP units per quart. This method has the advantage of efficiency: all the vitamin reaching the milk, whereas cows are very inefficient in making the transfer from their rations. It costs about ½ cent per quart. A psychological disadvantage is that a man-controlled addition has been made to a natural product.

These supplemented milks should be frequently and competently inspected to assure their uniformity, but a survey in 1948 showed that only 4 per cent of market samples contained less than 400 USP units per quart and most of these were only slightly deficient.[10] Because vitamin D requirements vary with such factors as season, age, and individual rates of growth, it is not desirable to produce a common milk supply that will meet maximum requirements. Children who do not take a quart of milk containing 400 USP units should have more of this vitamin from a drugstore product. Vitamin D in milk is stable to the heat of pasteurization, cooking, and canning.

The Digestibility of Milk

From its natural function, one would expect milk to be a food that is efficiently and comfortably digested. It should be remembered, however, that cow's milk was not designed for the human digestive mechanism. Upon reaching the stomach, milk is coagulated by the action of acid and enzymes. According to one theory, the function of the coagulation is to promote retention in the stomach for partial digestion there and for gradual passage to the duodenum, where digestion is completed. In general, the harder the curd formed, the slower the rate of emptying of the stomach, and the more likely that discomfort will follow. Cow's milk forms larger, harder curds in the human stomach than does human milk. Acidification by hydrochloric acid, a normal gastric secretion, creates optimum conditions for activity of both the enzymes producing coagulation and those initiating protein digestion. Cow's milk has a higher buffer value than human milk and hence takes longer to acidify to the stage where coagulation and stomach digestion take place. Cow's milk can be made to behave more like human milk by dilution, heating, acidification and homogenization,* though evidence on the usefulness of the latter for this purpose is not conclusive.

It has been discovered that certain cows give milk which naturally forms a curd much softer then average. This characteristic appears to be inherited and is usually possessed by some cows in every herd. Natural soft-curd milk contains lower proportions of casein, cal-

[10] Council on Foods, *J. Am. Med. Assoc.*, 137: 159 (1948).

* Homogenization is a process in which the fat globules of milk are greatly subdivided by forcing them through a small aperture.

cium, and phosphorus than does average milk and may require no modification when used for infant feeding. Soft-curd milk is also manufactured by removing about 20 per cent of the original calcium and phosphorus, a process which leaves it still appreciably richer in these constituents than human milk, and by limited digestion by pancreatic enzymes. The enzymes must be added before pasteurization and are sufficiently inactivated during that process to stop the digestion at the proper point. Soft-curd milks are available on the market in some larger cities. Although soft-curd milk may leave the stomach more rapidly than ordinary milk, and hence may be less often the cause of digestive discomfort in babies and some adults, there is no evidence that it is more completely digested than ordinary milk.

The length of time that milk remains in the stomach varies also with the amount taken at one time and with the presence or absence of other foods. A pint stays longer than ½ pint. Sipping causes coagulation in larger, harder curds than more rapid drinking. The presence of other foods increases the speed with which milk leaves the stomach. The size of the fat globules and the proportion of fat may also be factors in digestive comfort, but the evidence on this point is not clear cut.

Because milk tends to remain in the stomach longer than foods containing less protein and fat, such as fruits, some have wondered whether it might interfere with appetite if given between meals. In one study of the effect on food consumption of giving children a glass of milk 1 hour before meals, it was found that there was no difference in amount eaten at mealtime. Hence between-meal milk drinking would seem to be a desirable practice for persons who need to increase total food consumption.[11]

The Sanitary Quality of Milk

Milk is not only a relatively complete food for animals, but it makes a very favorable medium for the growth or survival of microorganisms, some of which are pathogenic to man. These have been mentioned in Chapter 3 and include, as transmitted from the cow, the bacteria causing septic sore throat, brucellosis, and bovine tuberculosis. Others with which milk may become contaminated, on its often devious route to a sterile bottle, are the organisms causing diphtheria, typhoid fever, scarlet fever, and certain dysenteries. A

[11] Wolman, *J. Pediat.*, 28:703 (1946).

commonly accepted index of the sanitary quality of milk is a bacterial count. According to the U. S. Public Health Service, "A high count does not necessarily mean that disease organisms are present, and a low count does not necessarily mean that disease organisms are absent; but a high bacterial count does mean that the milk has either come from diseased udders, has been milked or handled under undesirable conditions, or has been kept warm enough to permit bacterial growth. This means, in the first two cases, that the chances of infection have been increased, and, in the last case, that any infection which has reached the milk has been permitted to grow to dangerous proportions. In general, therefore, a high count means a greater likelihood of disease transmission. On the other hand, a wrong interpretation of the significance of low bacterial counts should be avoided, since low-count milk may be secured from tuberculous cows, may have been handled by typhoid carriers, and may even have been handled under moderately unclean conditions."

State or city standards for bacterial counts of raw milk vary considerably. The U. S. Public Health Service recommends defining A and B grades as follows:

1. *Grade A raw milk*, containing at least 3.25 per cent fat, having an average bacterial plate count of not more than 50,000 bacteria per cubic centimeter, and produced on farms conforming to certain specified sanitary standards.

2. *Grade B raw milk*, that which does not exceed a bacterial count of 1,000,000 per cubic centimeter.

In some markets a grade of raw milk known as *Certified* milk is available. Certified milk must conform to standards set up by the American Association of Medical Milk Commissions. Production must be supervised by the local medical society. The standards imposed include close supervision of the herd by veterinarians to determine its freedom from tuberculosis, Bang's disease, mastitis, and other diseases, immaculate cleanliness of the barn itself and of the cows, and the requirement that the milkers be clean, healthy persons. Chemical and biological requirements, including a butterfat content of at least 3.5 per cent and low bacterial count of less than 10,000 per cubic centimeter, are also defined.

Standards for certified milk increase the cost of milk to double that of ordinary milk, and less than 1 per cent of the total supply, most of which is used in infant feeding, conforms to them. The movement has, however, tended to raise the quality of market milk as a whole. Since pasteurization is now generally recognized to en-

sure sanitary safety of a degree not attainable in raw milk no matter how carefully produced, it is permitted in the preparation of certified milk though it is not as yet required. Certified milk may also be homogenized or otherwise treated to produce a soft-curd type.

Factors affecting the sanitary quality of milk, which may be reflected in its bacterial count, include the health of the cow, the health and hygiene of human handlers, barn and utensil sanitation, speed and degree of cooling, time of holding, and pasteurization. Fresh milk cannot be obtained in a sterile state, but the initial number of microorganisms can be cut down by sanitary handling. Their increase can be retarded by cooling immediately after milking and by holding at cool temperatures. The relative rates of development of bacteria in milk at 50 degrees F. and 68 degrees F. (10 and 20 degrees C.) are shown in Table XXXII. If milk is to retain high quality,

Table XXXII. The relative rates of increase of bacteria in milk at 68 degrees and 50 degrees F.

[After Rogers]

	Relative number of bacteria at the end of				
Temperature	0 hours	6 hours	12 hours	24 hours	48 hours
50 degrees F.	1	1.2	1.5	4.1	6.2
68 degrees F.	1	1.7	24.2	6128.0	357,499.0

it is essential that it be quickly cooled to 45 degrees F. (7 degrees C.) or below, and held at such temperatures. Most states have sanitary codes which specify in detail methods of controlling such factors, but, since adequate and frequent inspection is expensive and even a day's negligence in regard to any of the above factors by one contributing farm could infect the milk supply of many communities, increasing confidence is being placed on pasteurization as a means of ensuring a safe milk supply.

The Pasteurization of Milk. Pasteur found that a few minutes of heating at a temperature from 122 to 140 degrees F. (50 to 60 degrees C.) was sufficient to prevent abnormal fermentation in wine, because it killed the undesirable yeasts and molds which were responsible. This treatment came to be known as *pasteurization* and later was adapted to milk to improve its keeping quality. Because pathogenic organisms are killed at a similar temperature, pasteurized milk became recognized as a safe food. At the present time, the

emphasis on pasteurization is based on its effect on sanitary quality, but commercial considerations are involved in defining heat treatments which, on the one hand, kill all pathogens but, on the other, produce a minimum of effect on taste and cream line.

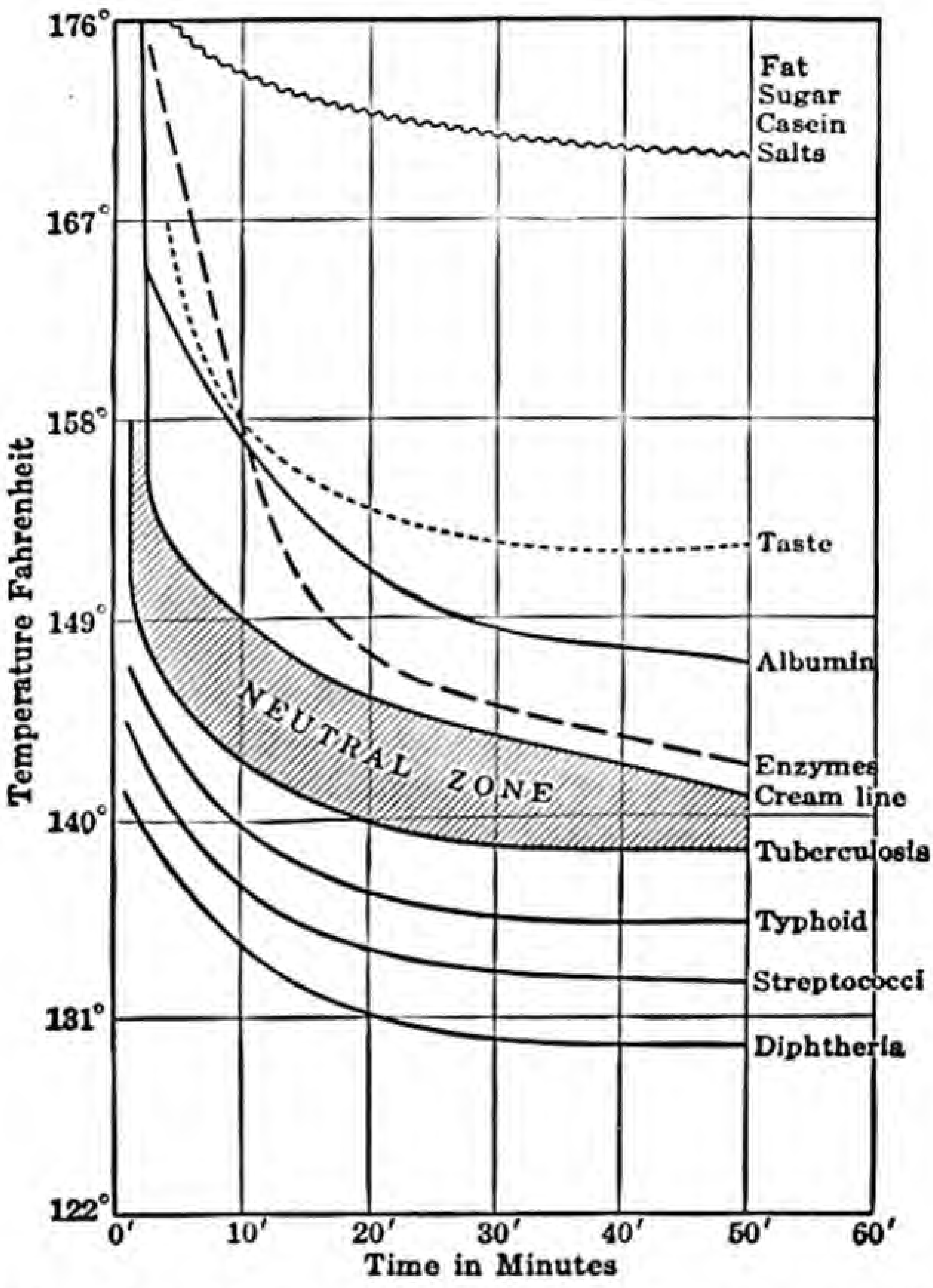


FIG. 12. Effects of time and temperature of milk pasteurization. (*After North.*)

The chemical and biological effects of various temperatures on milk are shown in Fig. 12.[12] As this figure shows, disease-producing organisms can be killed without affecting cream line or taste, either by short heating at a relatively high temperature or longer heating at a lower temperature. Two methods of pasteurization have accordingly been developed: the *hold* process in which milk is held at 143 degrees F. (61.6 degrees C.) for 30 minutes, and the *high tem-*

[12] North et al., *U. S. Public Health Service, Public Health Bull.* 147 (1925).

perature-short time process, in which milk is heated to a temperature of at least 160 degrees F. (71 degrees C.) for 15 seconds and then cooled. Either method produces safe milk which creams satisfactorily and which does not necessarily acquire a cooked taste.

Pasteurization kills all disease-producing organisms in milk, but it cannot remove filth or reverse any changes which might be produced by disease in the cow. Hence it should not be substituted for proper sanitation or for health inspection of the cows. The bacterial count before pasteurization helps to keep a check on the adequacy of these measures. Thus the United States Public Health Service in its definitions of Grade A and Grade B pasteurized milk designates that they shall meet specifications for the corresponding grade of raw milk before pasteurization. As in grades of raw milk, the adoption of these standards is a matter of local choice, and some cities define their grades differently. Grade B pasteurized milk is safe and wholesome, and, if available, should be the product chosen in the average household where the price premium attached to the A grade makes it an unnecessary luxury.

Bottled pasteurized milk can be safely kept at least 3 or 4 days at refrigerator temperatures which should preferably be 34 to 40 degrees F. (1.6 to 4.4 degrees C.) but never more than 50 degrees F. (10 degrees C.). In 1949 only 2 states had the important requirement that date of pasteurization, bottling, or sale be printed on the cap.

As a result of the increased use of pasteurization, disease transmitted by milk is diminishing. In 1949 milk and milk products were known to be responsible for 15 outbreaks with 246 cases and no deaths as compared with 367 outbreaks, 9043 cases and 11 deaths recorded for other foods. Properly pasteurized milk or products made from it are safe, and this is the most practical method of making them so.[13]

According to the United States Public Health Service, "The public-health value of pasteurization is unanimously agreed upon by health officials. Long experience shows conclusively the value in the prevention of diseases which may be transmitted through milk. Pasteurization is the only measure known which if properly applied to all milk will prevent all milk-borne disease. Examination of cows and milk handlers, while desirable and of great value, can be done at intervals only and therefore may permit pathogenic

[13] Note, *J. Am. Med. Assoc.*, 146: 52 (1951).

bacteria to enter the milk for varying periods before the disease condition is discovered. Disease bacteria may also enter milk accidentally from other sources such as flies, contaminated water, utensils, etc."

Formerly there was considerable prejudice against pasteurized milk, but, when the process is carried out according to proper modern methods, reasons for the prejudice no longer exist. Seasonal variations in the nutritional value of milk are of much greater significance than the effects of pasteurization. The nutritive changes actually caused by commercial pasteurization when properly carried out, amount to a loss of less than one-fifth of the iodine, thiamine, and ascorbic acid. All other components of known nutritional value are practically unchanged. Calves, rats, and children grow as well when given pasteurized milk as raw milk. As one American nutritionist has said, "We have an immense amount of clinical evidence gathered from many countries which shows that pasteurized milk has fulfilled the needs for feeding infants and children over many years, with no evidence of damage, provided the loss of vitamin C is made good. The opponents of pasteurized milk have conspicuously failed to make a case against it in favor of the raw product. The marked lessening of the incidence of intestinal troubles and contagious diseases carried by raw milk through pasteurization makes it hard to understand how opposition can longer be justified." [14]

Pasteurization does not affect digestibility unfavorably. In fact, the tendency of heating to result in the formation of softer curds in the stomach may facilitate digestion of pasteurized milk.

The taste or appearance of milk need not be adversely affected by pasteurization. Unfortunately the volume of cream on milk pasteurized at 145 degrees F. (62.8 degrees C.) is more than 10 per cent less than on milk pasteurized at a temperature three degrees lower. (See Fig. 12.) This difference is easily discernible to the consumer. One advantage of the homogenizing of market milk is the elimination of buying by the cream line, a practice that has been responsible for much pasteurization that was imperfect.

The cost of pasteurization in lots of reasonable size is a small item, estimates placing it at a little less than ½ cent per gallon. When the commercial supply of milk is unpasteurized, or when the safety of the supply of milk is questionable for any reason, pasteurization may be carried out in the home. Small inexpensive household pas-

[14] McCollum, *Am. J. Public Health*, 24: 956 (1934).

teurizers are available, or a suitable simple method is heating the milk quickly to 165 degrees F. (74 degrees C.) with constant stirring followed by immediate cooling. The cooling may be accomplished efficiently by placing the pan in cold water and continuing the stirring.

The Palatability of Milk

The flavor of fresh raw milk is attributed primarily to the lactose and chlorides it contains. Although proteins and fat probably do not influence flavor markedly, fat is related to palatability through its effect on viscosity and color. The quality of richness of flavor is attributed to phospholipids. The relative richness of buttermilk as compared to whole milk is probably caused by the release of these compounds from adsorption by the fat globules as these coalesce during churning.

Milk is susceptible to many flavor defects, including those derived from the eating of weeds by the cow, pathological udder conditions, absorption of environmental odors, contact with metals, electrolytic currents developed in containers exposing more than one metal to the milk, abnormal amounts of the enzyme lipase, oxidations, and the activities of contaminating bacteria. Inhaling the odors of silage or manure may also produce off-flavors in milk. Wild onions and garlic are examples of plants which may, when eaten by cows, impart a definite flavor to the milk. In some localities this difficulty has been so pronounced that methods for removal of the undesired flavors have been devised. Children may contract persisting dislikes for milk when they have tasted some with an off-flavor; hence it is important that such defects be minimized.

Of greatest importance to the dairy industry are the off-flavors associated with rancidity and oxidation. The former is largely a result of the activity of lipase: the hydrolysis of fats releasing short-chain fatty acids is accelerated and thus objectionable flavors ranging from a slight degree of rancidity to extreme bitterness are produced. Rancidity is less common than formerly because pasteurization under ordinary conditions destroys lipase.

The presence of an oxidized flavor is of primary concern because it has been estimated that from one-third to two-thirds of market milk may have such a flavor.[15] The development of an oxidized flavor is related to the reaction of the dissolved oxygen with the un-

[15] Herrington, *Milk and Milk Processing*, McGraw-Hill Book Co., New York, 1948, p. 221.

saturated fatty acids present. Numerous terms, such as tallowy, paperlike, or fishy, have been employed to indicate the variety of possible odors and off-flavors, depending on the particular fatty acid involved and the extent of the reaction. Some authorities believe that lecithin, in particular, is involved because the oxidation of the fatty acids in the lecithin molecule releases an amine group with a strong fishy odor characteristic of an increased degree of oxidation. Pasteurization and modern refrigeration practices inhibit the activity of bacteria which normally remove the oxygen, thus leaving it free to react with the fat. Certain metals, especially copper and its alloys, and exposure to ultraviolet rays in sunlight accelerate oxidation. The increasing use of paper cartons as milk containers may be beneficial in delaying the development of an oxidized flavor involving sunlight.

The whiteness of milk is a result of the scattering of light by the fat globules, colloidal caseinate, and calcium phosphate. When dispersions of each of these are prepared separately they are milky in appearance. The whiteness is always, at least in cow's milk, partially masked by the carotene dissolved in the globules of fat. Riboflavin is a yellowish pigment, but it is water-soluble and is found in the milk serum, outside the fat globules. As already stated the carotenes dominate the tendency to yellowness, and the intensity of this color depends upon the amount of them in the food of the cow and her capacity, which varies with the breed, to oxidize them.

Economy of Milk

Milk should not be compared with the cheap high-energy foods to estimate its real money value because its dietary importance lies in its capacity to supplement them. Milk contains proteins of high quality, and one way of appraising it is to compare the cost of protein from it with the cost of that from other animal sources. (See Table XXXIII.) With the usual prices for each kind of food it can be readily seen that whole milk is a cheaper source of protein than any other product, except those from processed forms of milk.

Even if milk were an expensive source of animal protein, it would still be indispensable for its calcium and riboflavin. For contributions of these and other minerals and vitamins, milk is one of the cheapest foods that we buy, but, because nutritional welfare is dependent upon increasing average consumption and because financial resources are a limiting factor in achieving this with many families, cutting its cost is a matter of general concern.

Table XXXIII. Animal protein equivalents (approximate)

[After Watt and Merrill, *U. S. Dept. Agr. Hdbk.* 8 (1950)]

1 quart of whole milk
1 quart of skim milk
17 ounces ($1\frac{1}{3}$ tall cans) evaporated milk
1 cup ($4\frac{1}{2}$ ounces) dry whole milk
$\frac{3}{4}$ cup ($3\frac{1}{2}$ ounces) dry skim milk
5 ounces Cheddar cheese
6 medium eggs
6 ounces lean meat or fish
10 tablespoons of cottage cheese

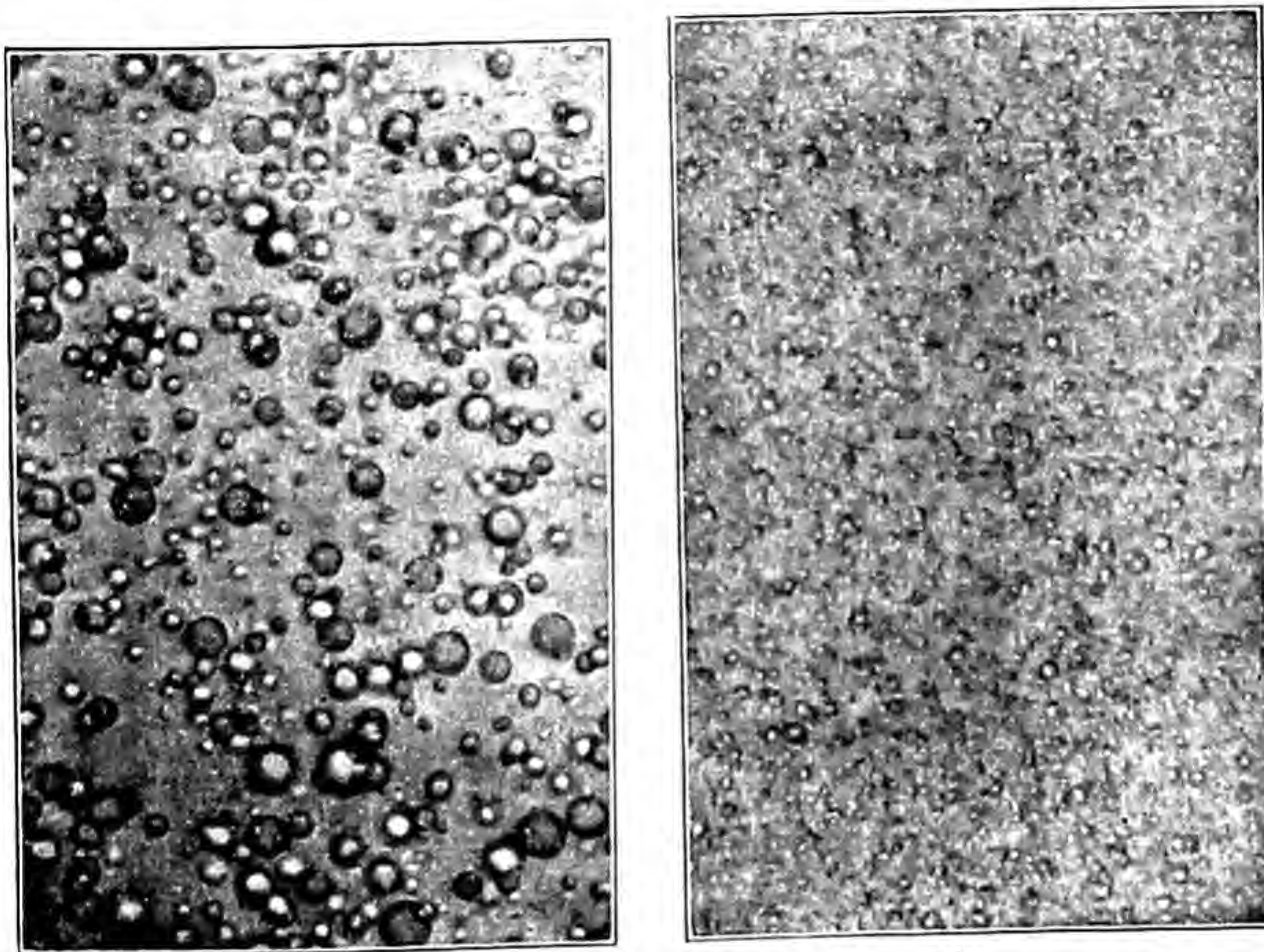
The principal methods of achieving lower milk prices are (1) more efficient production and distribution, (2) elimination of certain distributive services (such as doorstep delivery or everyday delivery), and (3) governmental subsidies, such as providing free or low-priced milk to school children and needy families. As we shall see later, skim milk and products made from it are relatively inexpensive because the demand for cream is much higher in relation to supply. Such whole-milk products as evaporated milk and cheese are also cheaper than whole milk because they are less perishable and can be stored or shipped from areas having lower costs of production. Also, in many states, the minimum price of fluid milk is controlled by law and all that cannot be marketed by that route is sold at lower prices for manufactured products.

Processed Milks

Homogenized Milk

Homogenization is a process in which milk or cream is forced through a small aperture under such a high pressure that the fat globules subdivide until their diameter averages only one-tenth of the original droplets. These newly formed globules immediately adsorb a layer of milk proteins which protects them from coalescence. The amount of surface is so greatly increased by homogenization that it has been calculated that 25 per cent of the milk protein is adsorbed in such milk, as contrasted with 2 per cent in the unprocessed milk. Homogenized fat globules do not clump; consequently, homogenized milk forms no cream line. The emulsion is extremely stable, and the globules move by Brownian movement rather than by gravitation. (See Fig. 13.)

Because homogenization prevents cream-line formation, it gives a more uniform product throughout the bottle. In distributing the fat, it also distributes the fat-soluble vitamins A and D. It also lowers the curd tension and imparts a richer flavor. If milk is to be homogenized it must be pasteurized to prevent the development of



(*a*) (*b*)

Fig. 13. The effect of homogenization upon the size of the fat globules in milk. (*a*) Fat globules in untreated milk (×1000); (*b*) fat globules in homogenized milk (×1000). (*Courtesy of Evaporated Milk Association.*)

rancidity which otherwise proceeds very rapidly, probably because of the greatly increased surface of the fat. Homogenized milk when properly refrigerated retains a fresh taste because the process retards the development of an oxidized flavor which may be induced by some factor during processing and holding. Milk fat is ordinarily so completely digested that, contrary to much publicity,[16] homogenization has little or no effect on this property.

Homogenization affects the stability of milk protein, perhaps as a result of the decreased motility of the adsorbed casein.[17] It is

[16] Trout, *J. Dairy Sci.*, 31: 627 (1948).

[17] Doan, *J. Milk Technol.*, Vol. I, No. 6 (1938), p. 20.

more subject to coagulation when heated in escalloped potatoes or when added to hot cooked breakfast cereal. But the concentration of calcium ions in the products being cooked, including the relative hardness of the water used, is of significance in the tendency to curdle.[18] White sauces and gravies made with homogenized milk have a separated, curdled appearance. This is a result of separation of the added fat; the tiny milk fat globules of homegenized milk are apparently so completely covered with protein that they do not combine with other fat. More than three times as much fat can be used in white sauces made with unhomogenized milk without separation. Beating the sauces made with homogenized milk during and after cooking increases their smoothness,[19] but has a tendency to result in pasty products. Restricting salt and adding it at the end of the cooking also helps.

Evidence regarding the effect of homogenized milk on the curd tension of baked custards is conflicting. In one experiment it was reported that custards made from homogenized milk have a lower curd tension and greater syneresis than those made from untreated milk.[20] Other workers, using a greater egg concentration, found that baked custards made with homogenized milk required more time to coagulate, had a higher curd tension, and were less subject to syneresis.[21] Perhaps variations in temperatures and pressures of homogenization as well as in proportions of ingredients may effect the gel strength of custards.

From the consumer's standpoint, the principal advantages of homogenized milk are its uniformity throughout the bottle and its possible taste appeal as a beverage and for use on cereals and puddings. Those who would use top milk instead of buying cream incur this extra expense by its use. However, many persons who formerly used top milk for cereal, pudding, or coffee are now satisfied to use homogenized milk. Observations appear to indicate that the absence of cream plugs, flecks, or butter granules in homogenized milk, and its uniform, fresh flavor offer particular appeal to children.[22]

[18] Hollender and Weckel, *Food Res.*, 6: 335 (1941).

[19] Towson and Trout, *Food Res.*, 11: 261 (1946).

[20] Hollender and Weckel, *op. cit.*, p. 335.

[21] Carr and Trout, *Food Res.*, 7: 360 (1942).

[22] Trout, *Homogenized Milk*, Memoir 9, Michigan State College Press, East Lansing (1950).

Skim Milk

The cream layer on milk formed by the lower specific gravity of the milk fat can be separated from the remainder of the milk by skimming. Machines called separators employ centrifugal force to remove the lighter fraction, often so completely that less than 1 per cent remains in the skim milk.

The effect on nutritive quality of skimming or separating milk is shown in Table XXIX. Skimmed milk retains most of the mineral and protein content of milk, but has less energy value and vitamin A because these are concentrated with the fat in the cream. Except for vitamin A, skim milk can be considered a very satisfactory substitute for whole milk with all its variety of nutritive essentials. Its low calorie value makes it especially suited to those who need to restrict their eating in the interest of weight control. So far as palatability is concerned, most people prefer whole milk on account of its flavor and color, probably because they are accustomed to it.

The fat in milk promotes the formation of soft curds in the stomach so that whole milk or cream drunk alone results in softer curds than does skimmed milk. This is not an important difference, especially when milk is drunk with meals.

Skimming has no effect on the sanitary quality of milk if it is done under proper conditions. When a separator is employed, the milk comes in contact with parts of the machine and with extra utensils. Of course, all such exposures increase the chance of contamination unless the utmost cleanliness is maintained. Skim milk should be pasteurized for human consumption.

Whenever skim milk of suitable sanitary quality is available for human consumption it is often priced at half or little more than half the price of a corresponding amount of whole milk. This makes it an extremely economical source of the most essential nutrients in milk. The nutritive virtues of skim milk are not sufficiently publicized to create a substantial retail demand for it in fluid form.

Evaporated Milk

Evaporated milk is produced by dehydration of fresh milk to about one-half of its original volume in a vacuum pan at 54 to 60 degrees C. (130 to 140 degrees F.), after a forewarming period of 10 minutes. It is homogenized to prevent the formation of a cream line, which is considered unsightly. According to federal standards, evaporated milk must contain at least 7.9 per cent fat and at least

25.9 per cent total milk solids. If it is fortified with vitamin D it must have a potency of at least 24 USP units per fluid ounce. This is at a level of 400 USP units per quart as reconstituted, and much of the evaporated milk now sold is so fortified at no extra cost. Disodium phosphate, sodium citrate or calcium chloride to the amount of 0.1 per cent by weight may be added. These salts stabilize the protein and reduce the tendency to coagulation during concentration.

When evaporated milk is reconstituted by return of the original water content it closely resembles fresh milk in nutritive value except for small losses of thiamine and a reduction of ascorbic acid by one-half or more. Neither is particularly important in relation to the whole diet.

Evaporated milk agrees well with babies—the amount of heat treatment that it has received causes it to form small soft curds. The heat also changes the protein so that many persons allergic to ordinary milk suffer no reaction from the evaporated product.

Evaporated milk is sterilized and consequently is not only an entirely safe food but one that keeps indefinitely until opened. Even then it keeps longer than fresh milk under similar conditions.

The principal handicap of evaporated milk is the cooked flavor it develops. This is not noticeable when it is incorporated in cooked food mixtures or flavored with vanilla, molasses, caramel, or fruit juices. In fact, many persons have developed a liking for plain evaporated milk by repeated tastings. For long storage (several months or more), evaporated milk should be held at refrigerator temperatures to prevent the deterioration in flavor and nutritive quality caused by a reaction between sugar and certain amino acids.

Slow freezing in the can damages evaporated milk just as it does fresh milk. The fat emulsion breaks, the protein is dehydrated, and the water freezes out in large crystals. These changes impair its usefulness in food preparation (except for whipping), but not its nutritive or sanitary quality unless the can springs a leak. Undiluted evaporated milk chilled to 32 degrees F. (0 degrees C.) or below will whip to make a temporary foam which can be used as a substitute for whipped cream in or on desserts. The foam formed with evaporated milk is unstable, presumably because the fat does not clump to stabilize it. Adding 2 tablespoons of lemon juice to the foam from 1 cup of evaporated milk and continuing the beating until the foam is very stiff somewhat increases the stability. Evidently the acid lowers the *p*H of the milk to the isoelectric point, precipitating

the casein adsorbed on the fat globules as a result of homogenization, and making it available to stabilize the foam at the air-liquid interface. So far as nutritive value is concerned, the substitution of whipped evaporated milk for whipped cream is desirable, especially for children.

Evaporated milk is nearly always cheaper than its fresh milk equivalent because it is largely manufactured from milk produced in low-cost areas and because the price of milk used for manufactured products is less than the controlled minimum price for fluid milk in many areas. Also costs of transportation and storage are less than for whole milk.

In general, evaporated milk is an economical source of the most important nutrients of milk—protein, calcium, and riboflavin. It may be used in undiluted form in much cooking, thereby increasing the "invisible milk" intake.[23] The sanitary quality of evaporated milk can be relied upon everywhere, which is not always true of fresh milk. Teaching children to accept it interchangeably with fresh milk saves money and ensures a safe supply wherever one travels. When served cold in a favorable psychological atmosphere, evaporated milk has been found to be well accepted in school lunches.[24]

Brands of evaporated milk vary in price, primarily according to whether they are nationally advertised—the advertised brands being sold at a higher price. All brands meet federal standards in composition; all are sterile and equally digestible. The principal difference is in flavor and this is not related to price.

Sweetened Condensed Milk

Sweetened condensed milk is manufactured by evaporating a mixture of sweet milk and refined sugar (sucrose) or sugar and corn sugar (dextrose) to a concentration of not less than 28.0 per cent of total milk solids and not less than 8.5 per cent of milk fat. The product is not sterile but it reaches pasteurization temperatures during processing and is preserved by the high concentration of sugar. Sweetened condensed milk retains the nutrients of the original milk but is so highly diluted with sugar that it is not a substitute for fresh milk, as is evaporated milk. It should be used only temporarily for infant feeding. In fact, it is suitable only for use in

[23] Balsley, *J. Am. Dietet. Assoc.*, 25: 58 (1949).

[24] Hollinger and Staples, *J. Am. Dietet. Assoc.*, 23: 972 (1947).

sweet food mixtures; for this purpose it is not as economical as a combination of evaporated milk and ordinary sugar.

Dried Whole Milk

Dried whole milk is milk which has been dried to a moisture content of no more than 5 per cent. It keeps better with a lower percentage of water, and most commercial products contain less.

The two principal methods used for removing water from milk are (1) the roller process, spraying the milk against the surface of a heated metal cylinder, and (2) the spray process, running a fine spray of milk into heated air. The spray process product is more easily reconstituted when water is added, because the protein has not been subjected to as high temperatures. Dried whole milk when reconstituted approximates fresh milk in nutritive value except for losses of vitamin C. Drying does not kill all pathogenic organisms; hence the milk should be pasteurized before drying. Dried milks have not been a health problem.

Dried whole milk must be tightly packaged to keep out air because it is very hygroscopic and, on picking up moisture, deteriorates rapidly. The color gradually takes on a brownish tint, an off-flavor develops and the biological value of the protein decreases. These changes are believed to be caused in part by a reaction between the sugar and free amino groups of the protein.[25]

The amount of fat present in dried whole milk is such that it is likely to oxidize and develop a tallowy flavor on exposure to air. The problems of flavor and keeping quality have made it impossible to create a demand for dry whole milk sufficient to make it compete with fresh milk on the average retail market.[26] It is not sold in most grocery stores. When available during the war, it was not priced so advantageously as evaporated milk.

Dried Skim Milk

Skim milk can be dehydrated by the processes used for drying whole milk. Because it is very low in fat it does not so readily develop the tallowy flavor associated with the whole milk product. However, if stored at high humidities and temperatures it cakes, is subject to the browning reaction, and suffers a loss in protein solubil-

[25] Anon., *Nutrition Revs.*, 9: 146 (1951).

[26] Coulter et al., in *Advances in Food Research*, edited by Mrak and Stewart, Academic Press, New York, 1951, Vol. III, p. 105.

ity and biological value. Storage in a refrigerator, especially for opened packages, is recommended because it is both dry and cool. If the product from an opened package is transferred to a tightly closed jar, it will keep for several months at room temperatures, however.

Reconstituted dried skim milk approximates the fresh in nutrients, except for vitamin C content, and in all other properties. It represents the best buy on most markets for the important nutrients of milk.

Dried skim milk can be incorporated in many food mixtures, including meat loaves, white sauces, cream soups, custards, puddings, and flour mixtures, with or without preliminary reconstitution, and in concentrations that fortify the food mixtures and the diet as a whole.

The optimum amount to be added varies according to the product. In sauces, soups, custards, and puddings viscosity increases in proportion to the amount of dried skim milk added. About 2 tablespoons per cup of milk has been found to be optimum for white sauce; otherwise the product is thick and sticky. However, approximately 1 cup of the solids can be added for 1¼ cups of flour in waffle batter with excellent results other than an increased tendency toward browning.[27]

In the proportion of equal parts of dried milk and water, it may be whipped and then flavored with sugar and vanilla. This makes a palatable, nutritious, inexpensive substitute for whipped cream either as a topping or incorporated in desserts. Less sugar needs to be added than in the case of whipped cream because the concentration of lactose in the dried milk makes the foam relatively sweet. Dried skim milk may also be used to fortify whole milk or milk drinks.[28]

Because many persons associate inferiority with the word "skim," Congress has authorized the use of the term "non-fat dry milk solids" and "defatted milk solids" as alternative designations. However, "non-fat milk solids" is currently favored commercially.

Frozen Milk

Everyone who has seen milk which has been frozen at outdoor temperatures has noticed that it does not return to its original structure on thawing. Slow freezing breaks the fat emulsion and changes

[27] Morse, Davis and Jack, *Food Res.*, 15: 216 (1950).

[28] "How to use whole and non-fat dry milk," *U. S. Dept. Agr., Leaflet* 275 (1949).

the protein, giving a curdled appearance. However, a process of freezing concentrated, pasteurized milk very rapidly and holding it at −10 degrees F. (−23.3 degrees C.) is being developed which gives a reconstituted product of natural appearance and flavor. If the problem of holding temperature can be solved this could become an important method of distributing milk.[29] At present, however, economic factors appear unfavorable, particularly the action of milk price control boards in classifying such milk with fluid whole milk, and distribution seems likely to be limited to localities where fluid milk is either unobtainable or costly.[30]

Concentrated Milk

In a number of areas, fresh pasteurized milk which has been concentrated to one-third of its original volume is being marketed on an experimental basis. Vacuum temperatures for concentration are low enough to prevent flavor changes. There is no significant change in nutritive value. Such milk has the advantage of being less bulky to transport and store than the original. Also, it may be used in the concentrated or partly diluted form as cream or for cooking, thus getting the nutrients of a much larger quantity of milk into an ordinary serving. The cost of concentration is partly offset by lower costs of containers, transportation, and storage. However, the same economic factors unfavorably affecting the sale of frozen concentrated milk appear to be operating in the case of concentrated milk also.[*]

Sterilized Milk

Milk with a fresh flavor which will keep sweet for several months without refrigeration is being produced on a small scale for shipments to foreign countries and isolated regions. The milk goes directly from the cow through a pipeline that keeps air out, to a vacuum tank. The tank is transported to the factory where, still without exposure to air, the milk is homogenized, flash-heated to 285 degrees F. (140.6 degrees C.) in a few seconds, cooled, and canned. This milk retains its original flavor and nutrients but is very expensive.[31]

[29] Gemmill, *Food Inds.*, Vol. 22, No. 6 (1950), p. 39. Also Anon., *Food Eng.*, Vol. 23, No. 7 (1951), p. 35.

[30] Doan, F. J., *Food Technol.*, 6: 402 (1952).

[*] Doan, *ibid.*, p. 402.

[31] Bloomberg and Hessey, *Food Eng.*, Vol. 23, No. 6 (1951), p. 71.

Milk Beverages

Malted milk is a dried combination of whole milk and a liquid obtained by cooking barley malt and wheat in water. Cocoa or chocolate is often mixed with it for making chocolate malted milk beverages. Federal specifications require not less than 7.5 per cent butterfat and not more than 3.5 per cent moisture. For its food value, see Table XXIX.

Another group of related products are mixtures of dried skim milk, malt, and cocoa or chocolate usually sold under brand names made up of some combination of the words chocolate or cocoa and malt. Their composition varies but they are generally high in sugar and constitute an expensive form of dried skim milk with flavor added.

The flavor of milk is often varied by combining it with other foods and flavoring substances. Malted milk has already been discussed. Café au lait is made by mixing hot milk with strong coffee in about equal amounts. It may be served plain or with sugar or cream or both. Eggnogs are a nutritive combination of milk and eggs. Chocolate milk drinks are by far the most popular of the milk beverages and are sold very generally in schools as well as in public eating places. They may be made from whole, skim, or partially skimmed milk and are flavored with chocolate or cocoa, sugar, and sometimes with added vanilla extract, spices, or malt. The viscosity of the milk may be increased by adding starch, dry skim milk, gelatin or various vegetable gums to help keep the cocoa particles from settling out. Homogenization or high temperature pasteurization prevents creaming.

In some states there are no standards for these products; they may be made from skim milk without designation, and there is no legal limit to the amount of dilution by the chocolate sirup that may be practiced. In other states or cities, chocolate milk must meet local standards for fat in milk or be labeled skim milk, or chocolate milk drink, or chocolate drink. The term chocolate-flavored milk or drink is used when cocoa is substituted for chocolate. Additional desirable specifications include permissible limits to the per cent of cocoa or chocolate and sugar to be added, and to the amount of dilution by sirup if that is the form of these ingredients, as well as appropriate sanitary qualifications regarding bacterial count and pasteurization.

The nutritive value of average chocolate milk approximates that of about nine-tenths the same volume of the corresponding whole or skim milk (the average volume of sirup added being about 1:10), plus about 50 calories of sugar. The contributions of the chocolate or cocoa in the ordinary 1 per cent strength are negligible. The effect of one serving a day of this product as a substitute for plain milk would be of no especial significance. If, however, an acquired taste for its chocolate or sugar makes a child refuse to drink plain milk, an unfortunate dilemma arises. On the one hand, if chocolate milk is not available at all times his milk consumption may be inadequate. On the other hand, drinking 3 glasses of chocolate milk adds 150 sugar calories to the day's food supply. This is such a substantial proportion of the total energy requirement of the child under 9 years at least, that it may be responsible for deficiencies of essential nutrients if not compensated for by a lower than average intake of sugar in other forms. Such compensation is unlikely because the chocolate milk is considered merely a form of milk, not a sweet dessert. These statements also apply to the food value of cocoa when it is made with whole or skim milk, and, since it is more often made with half milk and half water, the effect of the additional dilution must be taken into account.

The effect of chocolate on the digestibility of milk has been investigated. Although there is evidence that high concentrations (4 per cent) may decrease the completeness of digestion of the milk proteins, the usual 1 per cent concentration in chocolate milk or the amount in weak cocoa has probably only a negligible effect.

The physiological action of theobromine, caffeine, and tannin contained in cocoa and chocolate may be of more questionable consequence in relation to children's health. Theobromine and caffeine exert a stimulating effect on metabolism; tannin may be undesirable also.[32] Cocoa contains oxalic acid which interferes with calcium absorption.[33] The significance of these actions depends entirely upon the quantity of cocoa or chocolate consumed. Cocoa made with ⅔ teaspoonful per cup, is about one-third as potent as average coffee in stimulating quality, and probably negligible in its effect. But cocoa is often made with 1½ teaspoons per cup or more, probably undesirable amounts for a small child. There is a tendency to use excessive amounts in chocolate milk also.

[32] Mueller, *J. Dairy Sci.*, 25: 221 (1942).

[33] Mueller and Cooney, *J. Dairy Sci.*, 26: 951 (1943).

The sanitary quality of chocolate milk is frequently of questionable adequacy as a result of the contamination of the chocolate sirups used and of failure to pasteurize after the sirup is added to the milk. When skim milk is employed in making chocolate beverages, the selling price is likely to be considerably more than that of the plain product. As discussed previously, the food value of skim milk is so nearly that of whole milk that the principal concern of the nutritionist is merely that the purchaser knows what he is buying in order to judge the fairness of the price.

The principal role of chocolate milk should be to serve as a substitute for plain milk for persons who would not otherwise take enough milk, but there is no other valid reason for deliberately encouraging its use. When equally available there is evidence that children tend to prefer the chocolate product and, in general, it seems to be favored as a between-meal drink. It also appears that the consumption of milk could be increased even in competition with soft drinks if it were as readily accessible.[34]

Home methods of varying the flavor of milk or increasing its palatability for some, which are not subject to the disadvantages associated with chocolate or coffee when used for this purpose for children, include the addition of fruit juices, tomato juice, banana pulp, molasses, peanut butter, or spices.

Coagulated Milk

Complete coagulation of milk can be produced by extended heating, increase in acidity, or by the enzyme, *rennin*. In all methods the structural changes are dominated by alteration of the colloidal state of the calcium caseinate. The final product is a gel commonly known as clotted or coagulated milk. Syneresis, which may be accelerated by mechanical means such as cutting and heating, results in the production of a more concentrated gel—the curd—and the separation of a liquid—the whey. The curd produced by enzyme coagulation or souring is more or less completely separated from whey to provide the raw material for cheese making.

The Heat Coagulation of Milk. At 212 degrees F. (100 degrees C.) about 12 hours of heating is necessary to coagulate fresh milk completely, but at 266 degrees F. (130 degrees C.) only 3 minutes are necessary. These periods are less for evaporated milk,

[34] Ramstad et al., *Automatic Merchandising Increases Milk Consumption*, Cornell University School of Nutrition, Ithaca, N. Y. (September, 1951).

and the tendency to heat coagulation as the calcium caseinate becomes more concentrated constitutes one of the problems of the industry. The nature of the internal changes in heat-coagulated milks is not completely understood, but there is probably some release of calcium from the calcium caseinate molecules and clumping of the casein particles to form larger micelles. Deliberate coagulation of milk by heat is an uncommon household process, occasionally employed to produce a type of caramel pudding from sweetened condensed milk.

The Acid Coagulation of Milk. Acid coagulation of milk is produced naturally by the lactic acid formed from lactose by lactic acid bacteria. The relationship of temperature to the multiplication of bacteria in milk has been shown in Table XXXII. Normally, a large fraction of these bacteria are the lactic acid formers, and the rate of souring is related to the temperature of holding. Clotting or coagulation occurs after a certain stage of souring is reached.

Freshly drawn milk has a hydrogen-ion concentration of about *p*H 6.6. Milk begins to taste "sour" when about 0.3 per cent of lactic acid has been formed, and coagulation develops when 0.6 to 0.7 per cent of this acid is present. A portion of the lactic acid produced during souring combines with the calcium caseinate, forming calcium lactate and leaving free casein. As the *p*H approaches 4.6, the casein becomes insoluble and partially precipitates, producing the gel which characterizes milk at a certain stage of souring.

As mentioned previously, the acidity of milk increases slowly during heating. This, plus initial acidity which can vary considerably before taste is affected, may cause coagulation during relatively short heating of some milks which do not taste sour. This is especially likely to happen when salt is added, because salt increases the dissociation of the acid, freeing more hydrogen ions. Sour or "fermented" milk is entirely wholesome and is consumed by some peoples just as we consume fresh, sweet milk.

Ordinary buttermilk is a by-product of butter manufacture and has nutritive value similar to skim milk. Cultured buttermilks are made by fermenting skim milk with mixed cultures of bacteria, predominating in *Streptococcus lactis*, the kind causing natural souring.

Several forms of special acid-coagulated milk are available in markets in different areas. One which is currently popular is *yogurt*, the genuine form of which is made from concentrated whole milk fermented by a mixed culture of three organisms. Others are milks fermented by *Lactobacillus bulgaricus*, or *Lactobacillus acidophilus*.

All are sour but have different flavors. Acidophilus milk is occasionally fortified with lactose and prescribed for persons suffering from excessive intestinal putrefaction. The theory in such cases is that the acidophilus bacteria, which ferment carbohydrates rather than putrefy proteins, will depress and supplant the putrefactive types.

Kefir and *kumiss* are self-carbonated, fermented milk beverages made from whole, partially skimmed, or skim milk. Besides acid-producing bacteria, lactose-fermenting yeasts which produce carbon dioxide and alcohol are added.

Despite claims of special health values for fermented milk, just now for yogurt in particular, there is no scientific evidence that these products have any value other than that of the nutrients of the type of milk from which they are made. Since they are usually more expensive than the skim or whole milk entering into them, the purchaser is paying a premium for palatability qualities. Souring cannot be depended upon to destroy pathogenic organisms; hence all these products should be made from properly pasteurized milk and handled as carefully as fresh milk.[34a]

Rennin Coagulation of Milk. The calcium caseinate of milk may also be coagulated by action of the enzyme, rennin, under proper conditions. Rennin, which is normally present in the human stomach, is available in a commercial preparation called rennet. This is usually made from the fourth stomach of the suckling calf or lamb. Rennet may be concentrated to form powders or tablets, of which junket is an example. It has been estimated that 1 part of pure enzyme will coagulate 3 million parts of milk. Rennet is a dilute form of rennin, but in commercial cheese making only 1 part is added to 4 or 5 thousand parts of milk.

Experiments indicate that there are two stages in the process of curd formation by rennin. The first stage is an alteration in the casein itself, resulting in a much less stable compound known as calcium *para*caseinate. The second stage is a slow precipitation of the calcium *para*caseinate to form a gel. In a slightly acid solution, the rennin particles are positively charged. Over a wide range of hydrogen-ion concentrations, calcium caseinate particles are negatively charged. When the two are mixed, the rennin particles unite with the calcium caseinate particles and greatly reduce the charge they carry. This product is calcium *para*caseinate, and its forma-

[34a] Wilson and Tanner, *Food Res.*, 10: 122 (1945).

tion is the first stage in rennin coagulation. The second stage, the slow precipitation, occurs whenever free positive ions such as calcium ions are present, and when the temperature ranges between 50 and 150 degrees F. (10 and 65.6 degrees C.). The optimum temperature range is 104 to 108 degrees F. (40 to 42 degrees C.). An increase in hydrogen-ion concentration facilitates rennin coagulation. When milk has been overheated, the calcium caseinate is not readily coagulated by rennin. In experiments, coagulation of such milk has been produced by increasing the concentration of the calcium ions; hence the failure to coagulate is no doubt a result of the precipitation of calcium salts by heat, as mentioned previously.

Junket desserts are the product of rennin coagulation of milk to which sugar and other flavoring materials have been added. Stirring and jarring must be avoided to keep the clot intact and to prevent syneresis, which readily develops. Keeping the clot cold (in a refrigerator) also helps achieve this result. Rennin coagulation merely changes the texture of milk. It does not alter flavor or food value.

Cooking with Milk

When milk is heated a number of changes take place, many of them resulting from the effect of heat on the stability of the colloidal components. The familiar sign of one of these transformations is the appearance of a scum which contains coagulated casein. As soon as one coagulated film is taken off, another forms. During heating, a portion of the calcium is split from the calcium caseinate. With prolonged heating, complete coagulation of milk takes place. This does not happen in ordinary cooking.

When milk is heated, the lactalbumin forms a flocculent precipitate rather than the solid mass formed by heating egg albumin. This precipitate collects on the bottom of the pan and it tends to cause scorching, particularly when the milk is in a deep layer, not stirred briskly, or in a pan over direct heat instead of hot water.

The degree of dispersion of the colloidal phosphate is diminished by heating milk, and part of it precipitates. Iodine tends to be driven off. Heat causes a slight but continuous increase in hydrogen-ion concentration. This has been shown to follow lactose decomposition and is probably caused by the formation of lactic and formic acids. The change may cause a sudden and unexpected coagulation in milk that was sweet when cooking started.

When fluid milk is heated for an extended period, it is subject to the browning reaction caused by union of free amino groups with sugar. The cooked flavor is attributed in part to this reaction but especially to the liberation of sulfides.[35] It develops momentarily at 169 to 172 degrees F. (76 to 78 degrees C.), or on holding 30 minutes at 158 to 162 degrees F. (70 to 72 degrees C.). Although fat may rise to the top in cooked milk, most of the globules have coalesced as a result of the effect of the heat on the protein films. Cooked milk does not "cream" normally.

In its effect on nutritive quality, cooking causes partial inactivation of the vitamin C, but a short period of boiling may be less destructive of this component than the prolonged heating which occurs in some methods of pasteurization. There is also a small loss in thiamine potency, and, unless milk is covered to protect it from light, riboflavin inactivation proceeds rapidly. The nutritive loss caused by precipitation of calcium is not significant. Boiled milk forms small curds in the stomach which offer much surface for the action of the digestive juices, and it leaves the stomach more rapidly than does raw milk. Persons who think that milk disagrees with them may find that this is not true if it is boiled. As with evaporated milk, cooked milk is less likely to be responsible for allergies. The sterilizing effect of boiling makes such milk one of the safest forms of this food.

Sour Milk in Cooking

Sour milk is commonly used in flour mixtures to which baking soda is added. The acid of the milk reacts with the soda to set free carbon dioxide which may serve as a leavening agent. Because the acidity of sour milk varies greatly, and because there is no practicable home method of measuring it, one must use judgment in varying the amount of soda to be used. Less than one-half teaspoon of soda is recommended for each cup of milk that is not completely soured; otherwise an excess of soda will remain in the baked product. The color of such a product is inclined to be unattractively yellowish, the flavor bitter or soapy.

Prevention of Coagulation by Added Acids in Food Mixtures Made with Milk

In heating foods in which milk and acid are combined, such as cream of tomato soup, coagulation may occur if special precautions

[35] Gould and Sommer, *Mich. Agr. Expt. Sta. Tech. Bull.* 164 (1939).

are not taken. Neutralizing the acid with soda is effective, but may have an undesirable effect on flavor (depending on the amount used) and on retention of vitamin C, if it is present. In making cream of tomato soup, preliminary thickening of the tomato or milk with flour or cornstarch binds some of the acid. Flour may be more effective because its protein has a buffering action. Stirring the hot mixture into the cold milk to spread the acid through the milk and heating rapidly and serving promptly to reduce further formation of hydrogen-ions from the cooked milk also tend to prevent coagulation. If milk is very cold, it is possible to combine a considerable proportion of cold fruit juice with it without producing coagulation.

CREAM

The fat in normal, freshly drawn milk is distributed as individual globules varying in size from 0.10 micron to 20 microns in diameter, with an average of 3 microns. The size varies with the breed (Jerseys and Guernseys producing milk with larger fat globules and Holsteins producing milk with globules averaging 50 per cent smaller) and other factors. As already stated, these globules are protected by films of protein and phosphatides, but in time they tend to adhere to one another to form clumps at rates varying with temperature, agitation, acidity, and the number and size of the globules themselves. As clumping progresses, the emulsion becomes less perfect, and because fat has a lower specific gravity than the rest of the milk, the clumps of globules and larger single globules rise to the top, forming what is known as the cream layer. The homemaker is interested in creaming, because she attaches much importance to fat content in judging milk quality, and the volume of the cream layer is to her an apparent measure of that component. Moreover, the layer of cream affords a convenient means of separation if one wishes to consume it separately from the milk.

The volume of the cream layer is, however, affected by several factors which interfere with its reliability as an indicator of fat content. If the pasteurization temperature for the hold process goes as high as 145 degrees F. (62.8 degrees C.), cream volume is diminished, but heating at 142 degrees F. (61.7 degrees C.), followed by rapid cooling to 45 degrees F. (7.2 degrees C.) or below, results in practically no decrease. Both temperature of storage and the

length of the storage period also affect the volume of the cream layer.

Besides being used in the manufacture of butter which will be discussed in Chapter 13, cream is used primarily as light cream for coffee, as heavy cream for whipping, and in mixtures for making ice cream. In composition it represents milk with a high concentration of fat. Ordinary cream separators can be set to vary the concentration up to as high as 70 to 75 per cent fat, a product almost solid in texture. On farms where the relative price of butter and cream justifies the practice, this may be used in place of butter, or it can be "worked" in the usual way to give true butter. For commercial use, separators are available which may give a cream containing 80 per cent fat, the federal minimum for butter. This product is called plastic cream and is used for the manufacture of butter, for which it requires only "working," and for dairy spreads and ice cream. Plastic cream differs from butter in that the fat remains in its original emulsified condition, though the globules are so closely packed that they are deformed.

According to federal standards, coffee cream (light cream, table cream) must contain not less than 18 per cent of milk fat, and whipping cream not less than 30 per cent. Viscosity is a much-studied property of both types because the consumer employs it as a rough indicator of richness or amount of fat. It is increased by large size of fat globules, aging up to forty-eight hours, low temperature during storage and separation, and homogenization, as well as by the fat content. If employed at all, homogenization must be conducted at very low pressures because it promotes "feathering" (curdling or "flaking") when the cream is added to coffee, and because it interferes with whipping quality. Pasteurization tends to diminish the viscosity of cream somewhat, but differences in pasteurization temperatures appear to have little effect; a temperature of 175 degrees F. (79.4 degrees C.) has the same effect as a temperature of 143 degrees F. (61.7 degrees C.).*

The Appraisal of Cream

As a consequence of its fat content, cream is higher in energy value and vitamin A than milk. (See Table XXIX.) The fat in milk promotes the formation of soft curds in the stomach, so that

* Herrington, *op. cit.*, p. 225.

whole milk or cream drunk alone results in softer curds than does skimmed milk. This is probably not an important difference when milk is drunk with meals. Milk fat delays the emptying of the stomach just as do other fats, so that the drinking of rich milk or cream may cause a disagreeable heavy feeling. Small amounts of cream and reasonable quantities of ordinary rich milk seldom cause discomfort, however, and are valuable foods to prevent the onset of hunger before the usual mealtime.

Cream requires pasteurization for sanitary safety.

The demand for cream rests largely upon its appetite appeal when it is added to other foods. It is a relatively expensive food because (1) milk fat costs more to produce than equivalent fortified vegetable fat, (2) many consumers have an exaggerated opinion of its nutritional value, (3) skim milk is not appreciated as it should be for human consumption, and consequently sells at bargain prices, and (4) it is in high demand for its palatability, particularly in the form of ice cream.

So far as the fat content of either cream or milk is concerned, consumer welfare is probably best met by inspection adequate to ensure the meeting of established minimum standards. Although the consumer should not pay for fat that is not present, emphasis upon quantitative visible evidence of its presence encourages market practices to magnify such evidence and discourages the use of safe pasteurization temperatures. From a nutritive standpoint, the solids other than fat are more important in milk and in all its products except butter than is the fat itself.

Whipping Cream

As stated previously, cream is essentially a concentrated emulsion of milk fat in milk plasma, which is water containing proteins in colloidal dispersion and salts in true solution. When cream is whipped, the structure increases in complexity, owing to the incorporation of air bubbles and the production of a foam. The air bubbles are surrounded by protein films in which lie clumps of fat globules and which, if cold, give rigidity and permanence to the structure. (See Fig. 14.) In a properly whipped cream all of the liquid is retained in these films, probably by capillary attraction. When agitation is excessive, the fat emulsion breaks and butter is formed.

Desirable whipping qualities include the capacity to form a large volume of stiff whip and to retain it relatively permanently with little drainage. Because the air bubbles are trapped by protein films, sufficient protein in an altered form must be present to produce these films. The fat clumps stiffen the films and cause the surface to be-

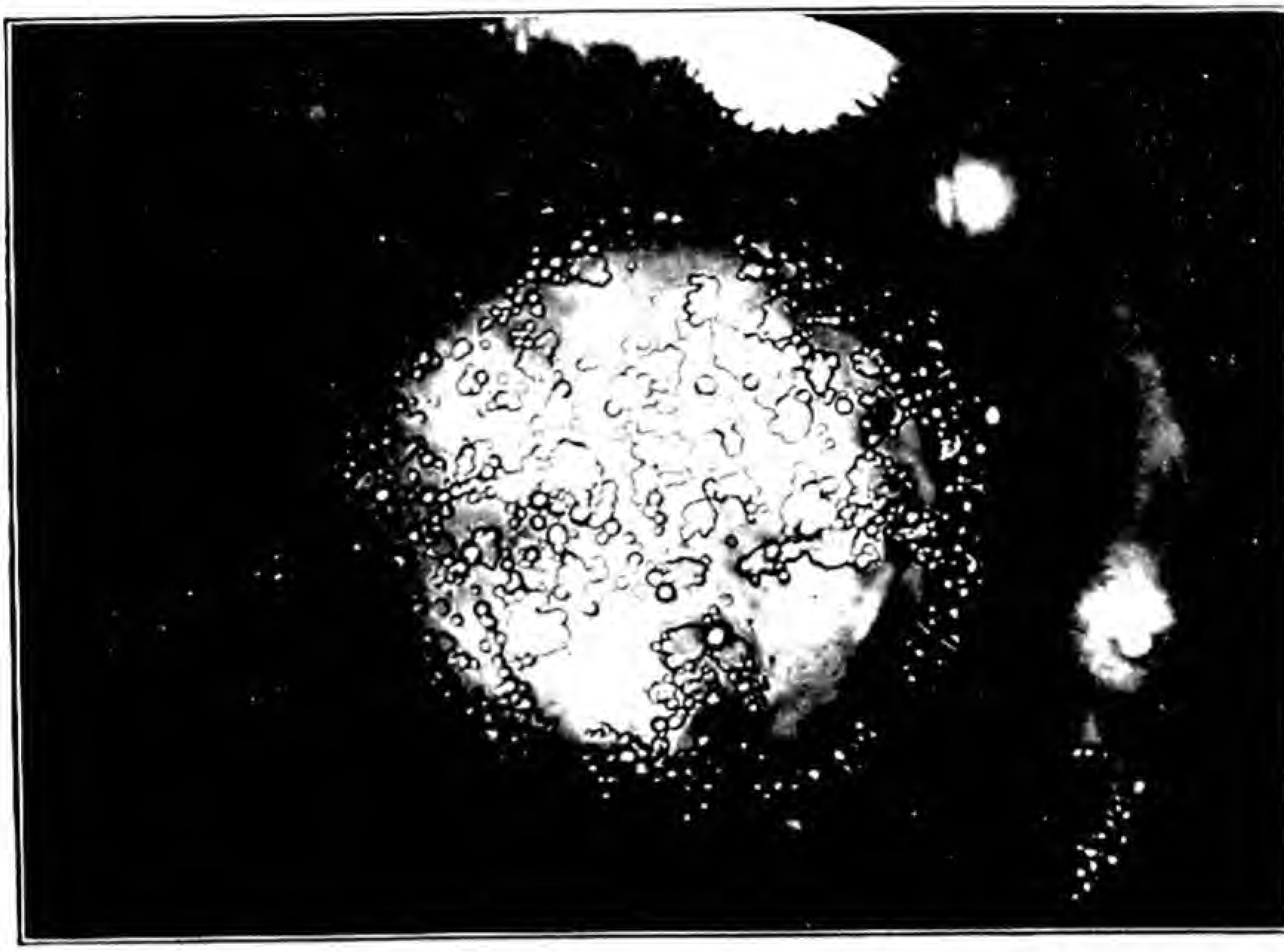
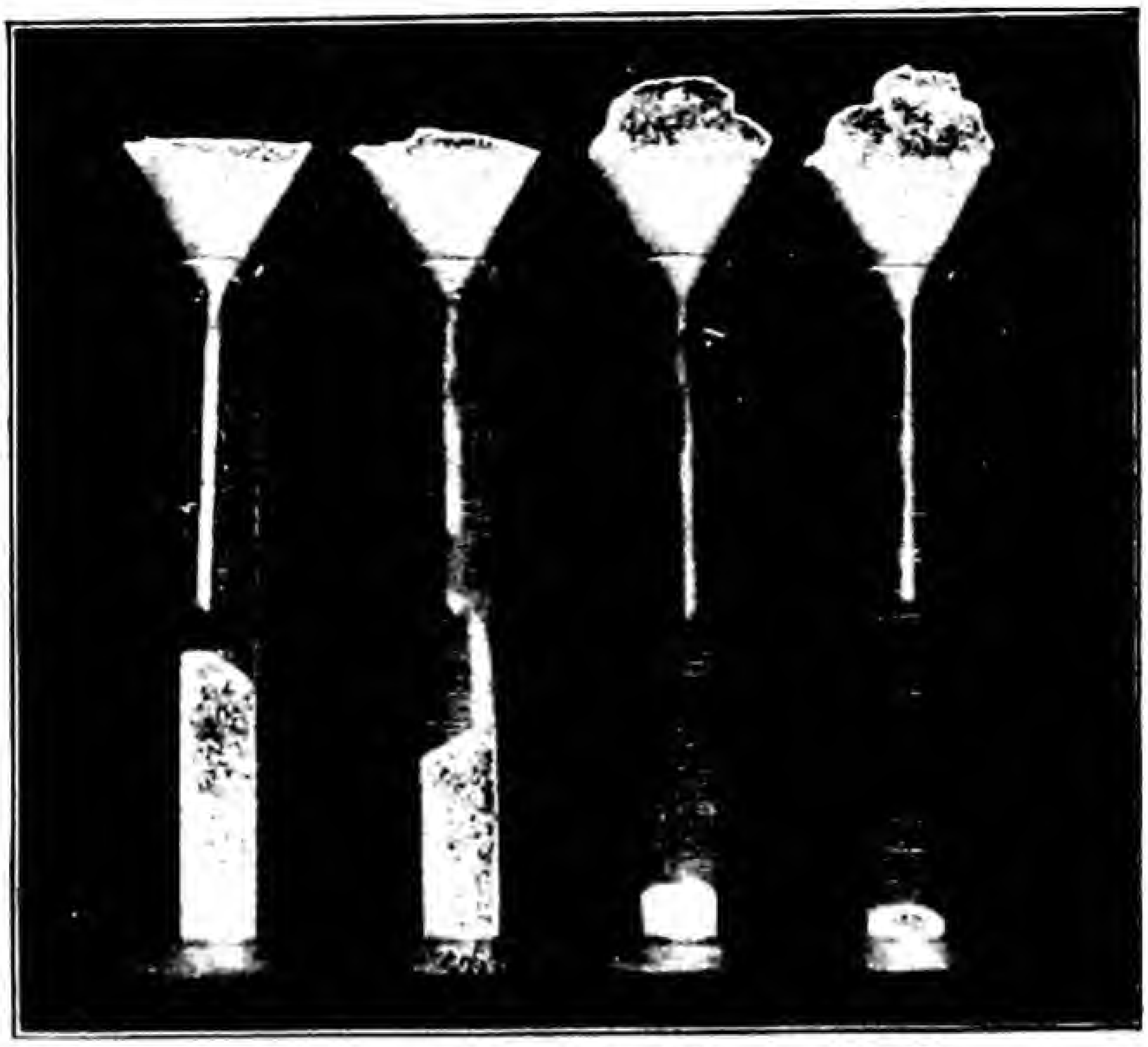


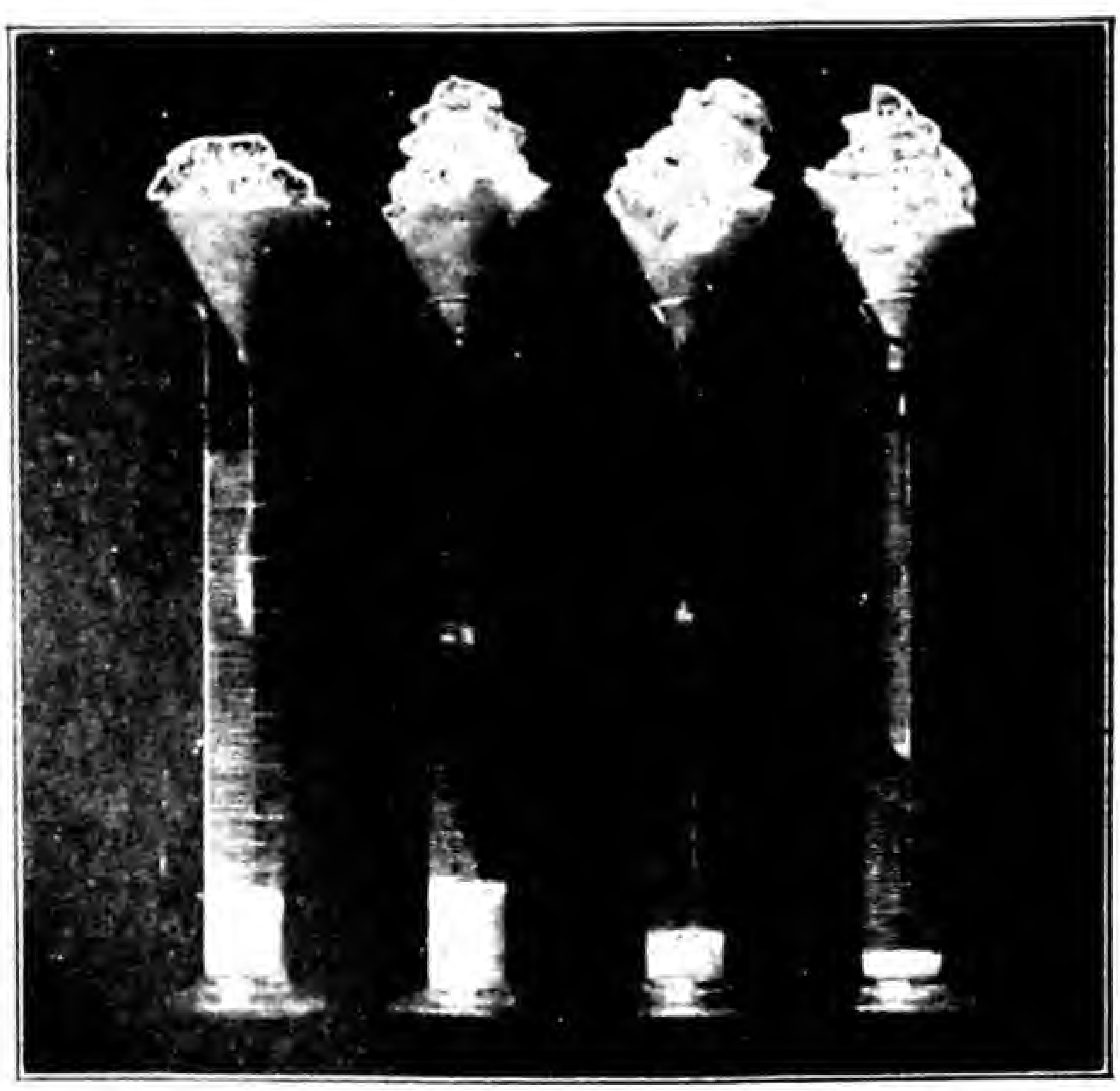
FIG. 14. Photomicrograph of whipped cream, showing a large air cell surrounded with fat globules. The clustering of the fat globules prevents the air from escaping from the whipped cream and also prevents drainage of fluid from the whipped product. If the fat is chilled, it aids in keeping the cream in a stiff mass. (*Courtesy of J. C. Hening.*)

come very great by making a high degree of subdivision of air bubbles possible. Large surface results in thin films, in which the protein becomes more or less denatured and consequently permanently firm, and in tenacious holding of the liquid, giving a dry whip which does not drain on standing.

Cream whips best with household types of beaters in only a small volume (not more than a pint) at a time. The blades of the beater should not be completely submerged in the cream. The container should be large enough to allow for doubling in volume plus some height for splashing. Fast beating which doubles volume in 2 to 3 minutes is desirable.



(*a*) 20% 25% 30% 35%



(*b*) 20% 25% 30% 35%

FIG. 15. Effect of percentage of fat on stiffness of whip: (*a*) Cream whipped immediately after separating; (*b*) cream whipped after aging for 24 hours. Photographs made after whipped cream had stood 18 hours at 40 degrees F. (*Courtesy of J. C. Hening.*)

Variations in the whipping quality of cream are related principally to the amount of fat and size of globules present and to environmental factors which affect the solidity of the fat and the tendency of the globules to clump. Volume and stiffness of whip have thus been found to be affected by (1) the temperature of the milk at separating time, (2) the age of the cream, (3) the percentage of milk fat which it contains, (4) temperature at time of whipping, (5) previous processing, and (6) additions of such substances as sugar. If milk is too warm when separated, a cream is produced which increases but little in viscosity with aging. This makes it less desirable for whipping. Cream that is at least 24 hours old whips better than that more recently drawn. If it is necessary to use younger cream, it should be cooled to as near the freezing point as possible. The percentage of milk fat is important. Twenty per cent will whip, but stiffness increases with additional fat, so that a 30 to 35 per cent cream is desirable. Above this proportion, the whipped cream tends to become buttery and lumpy. (See Fig. 15.) The larger the globules, the stiffer is the whip; hence Jersey and Guernsey cream are somewhat superior to Holstein and Ayrshire cream for this purpose. The cooler the cream, the harder is the fat, and the firmer are the clumps that are produced. To ensure good whipping, the temperature of the cream should not exceed 45 degrees F. (7 degrees C.). Forty degrees F. (4 degrees C.) is better, especially for the less rich cream. (See Fig. 16.) Cream whipped at 68 to 70 degrees F. (20 to 21.1 degrees C.) will not whip normally but becomes granular and buttery.

Such previous processing as the heating during pasteurization may be slightly detrimental to whipping quality. Drying or cook-

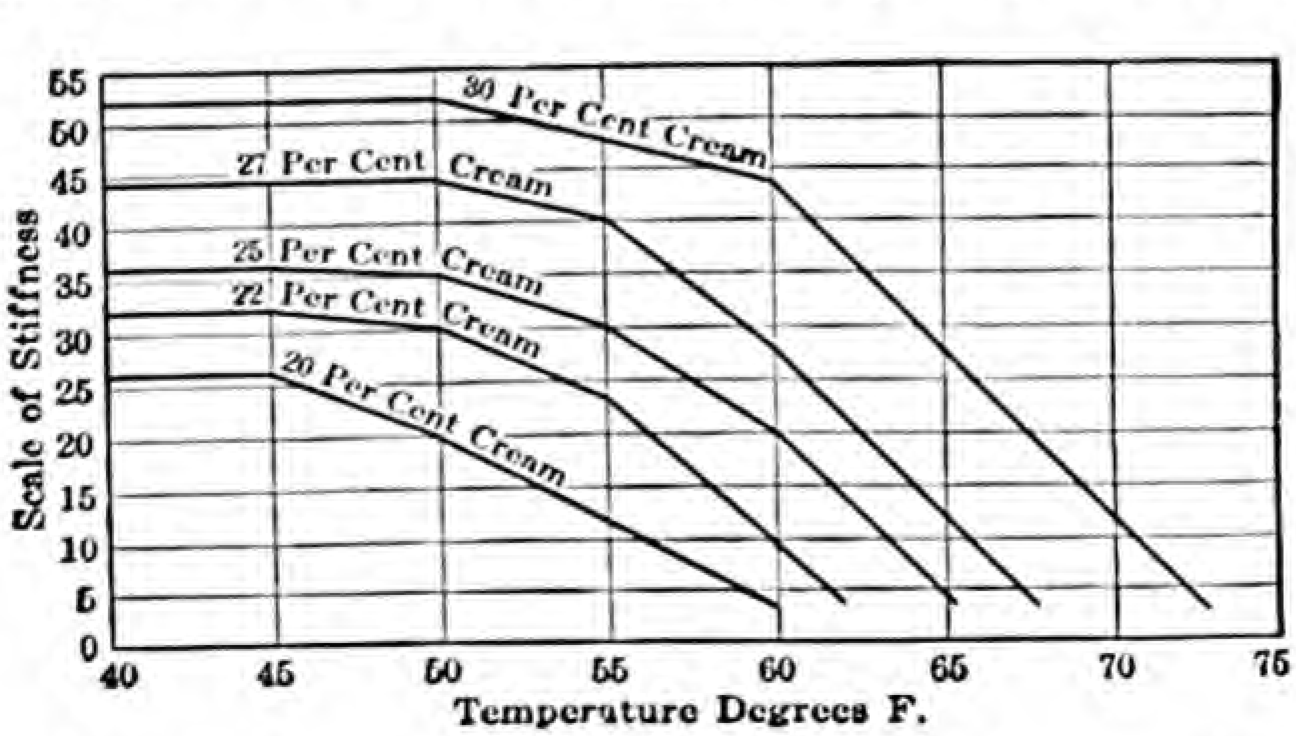


FIG. 16. The relation of temperature to stiffness of whip in cream. (*From Babcock.*)

ing cream destroys its whipping quality, probably because the proteins are altered. Complete freezing, especially of raw cream, may make it unsatisfactory for whipping, but it has been reported that complete freezing after pasteurization may be only slightly detrimental. Cream homogenized at more than very low pressures may not whip.

The addition of more than a very small amount of sugar before whipping decreases volume and stiffness, and it should be withheld until the whipping is almost complete. A considerable increase in acidity does not reduce the whipping quality.

Various aids to improve the whipping quality of light cream have been suggested. Sucrate of lime or Viscogen, which is prepared by mixing limewater and sugar, is the common component of the products on the market sold to make light cream whip. The action of the calcium sucrate has been explained as the result of the formation of insoluble tricalcium phosphate, which tends to carry down casein as it precipitates. It is this double precipitation which increases viscosity and improves the whipping quality.[36] However, probably neither the use of sucrate of lime nor the addition of a considerable quantity of acid is effective in achieving a satisfactory whip with 19 per cent cream, because there is not enough fat present to give sufficient stiffness even if it is well clumped.[37] The addition to cream of skim milk powder in the form of a cold paste improves it for whipping purposes by imparting a desirable flavor, giving a closer, smoother texture, increasing permanence, and giving a desirable glossy appearance.

The stability, permanence, or "standing-up" quality of whipped cream is affected by the temperature at which it is held, the amount of fat it contains, and the stiffness of the original whip. If whipped cream is held at temperatures below 50 degrees F. (10 degrees C.), it stands up for several days. The richer the cream and the stiffer the original whip, the greater is the stability.

Liquid cream saturated with nitrous oxide under pressure and sealed in a siphon can is available on the retail market. When the pressure is released, a foam is instantly formed. The process makes possible the production of as small amount of whipped cream as desired at any one time. The foam is relatively unstable and differs

36 Pyne, *J. Agr. Sci.*, 19: 463 (1929).

37 Dahlberg, *N. Y. State Agr. Expt. Sta. Circ.* 197 (1943).

in body from that of cream whipped by mechanical means, as the fat is not clumped to give rigidity.[38]

CHEESE

Cheese making is a process of fractionation of milk in which milk is coagulated and a more or less complete separation of curd and whey is effected, the curd being used for the cheese. The whey consists of water and most of the substances in milk in true solution, that is, the sugar and soluble mineral salts and vitamins, together with much of the lactalbumin. The curd contains the calcium caseinate, which has become *para*caseinate if rennin coagulation has been employed, or in part free casein if the coagulation was the result of increased acidity. Most of the fat remains entangled in the casein or *para*caseinate gel. This gel also contains much of the colloidal calcium phosphate and portions of the minerals and vitamins that are adsorbed or are in solution in the water that is retained.

Rennet-produced curds retain more of the calcium salts than do acid-produced curds. A coagulum produced by rennet is much more elastic and more likely to contract without mechanical treatment to squeeze out the whey. Furthermore, because rennet curds are more nearly neutral in reaction, they are more favorable media for the development of a greater variety of microorganisms and consequently offer possibilities for production of a greater variety of cheeses.

There are probably about eighteen distinct varieties of cheese, but over four hundred names are used, many derived from the name of the place of origin. The type produced depends primarily upon:

1. The fat content of the milk—whole, partly skimmed or skimmed.
2. The source of the milk—cow, sheep, or goat.
3. The method of coagulation—rennet or acid.
4. The moisture content of the cheese—soft, semihard, or hard.
5. Changes after curd separation—ripened or unripened.

The two factors accounting for the most pronounced differences in commercial cheeses are moisture content and ripening. On the basis of moisture content, cheese may be divided into two classes: (1) soft cheeses, which contain 40 to 75 per cent moisture and which

[38] Getz et al., *Food Res.*, 2: 409 (1937); Graham, *Food Technol.*, 4: 225 (1950).

are quickly perishable, and (2) hard cheeses, which contain 30 to 40 per cent moisture and which may be kept a year or longer under favorable conditions. The percentage of moisture left in the curd is regulated by the amount of cutting and stirring that it receives, the amount of acid developed, the amount of heating employed, and the amount of pressing it is subjected to.

Ripening is the term applied to the changes in composition, flavor, and texture that take place in cheese between the time when it is a tough, rubbery, elastic substance known as green cheese and the time when it has acquired the richness of taste and mellowness of texture usually associated with highest palatability. These changes are, for the most part, brought about by a definite sequence of species of molds or bacteria, a particular sequence being characteristic for each cheese and being controlled by such conditions of the manufacture as temperature of heating the milk, amount and method of adding the salt, amount of water present, curing temperatures and humidities, and method of coagulation, as well as by the kind of organisms with which it is inoculated. The changes associated with ripening result from a breakdown of lactose by microorganisms, partial digestion of the proteins to proteoses, peptones, and amino acids, and some hydrolysis of fat. Flavoring substances, mostly esters originating from the products of fermentation, are also formed. The bacteria participating in the ripening of some cheeses produce gases which form holes in the cheese. Most of the commercial cheeses are made from rennin-coagulated curds.

Some common commercial cheeses are classified in Table XXXIV. Most of those originating in other countries are now also made in the United States. American Cheddar cheese is ripened in drums or cylinders of different sizes with the following approximate weights: young Americas, 7 pounds; daisies, 20 pounds; flats, 30 pounds; Cheddars, 60 pounds.

In the household, an unripened acid curd cheese known as cottage cheese is commonly prepared. The texture of cottage cheese is affected by the temperature of heating, high temperatures and prolonged heating tending to make the curd tough, rubbery, granular, and dry. The maximum temperature should be 110 to 120 degrees F. (43 to 49 degrees C.). The acidity of the flavor may be lessened by washing the heated curd in water. One hundred pounds of skimmed milk of good quality yields between 15 and 18 pounds of cottage cheese. American Cheddar cheese can also be made under household conditions.

Table XXXIV. Principal varieties of cheese

Name and type	Country of origin	Ripening	Use
Soft			
Brie	France	Mold, 3–5 weeks	Dessert, appetizer
Camembert	France	Mold, 1–2 months	Dessert, appetizer
Cottage, pot or farmers'	Unknown	None	Salads, in cooking
Cream	United States	None	Salads, spreads, etc.
Neufchâtel	France	None	Salads, spreads, etc.
Hard or semihard			
American	(See Cheddar)		
Bleu or blue	France (now made in Denmark, U. S., South America)	Mold	Appetizers, spreads
Cheddar (American)	England (now made in U. S. and called "American")	Bacteria, 4 weeks–2 years	Salads, sandwiches, cooking, dessert
Bel Pease	Italy	Molds, 3 months	Desserts, spreads, appetizers
Brick	United States	Bacteria, 2 months	Sandwiches, cooking, dessert
Caciocavello (Provolone)	Italy	Bacteria (smoked)	In sauces, sandwiches, etc.
Edam	Holland	Bacteria, 6–8 months	Sandwiches, dessert
Emmenthaler	Switzerland	Bacteria, 6–10 months	Sandwiches, cooking, dessert
Gjedeost or Gjetost	Norway	Bacteria	Dessert
Gorgonzola	Italy	Mold, 3–12 months	Salads, dessert
Gouda	Holland	Bacteria, 6–8 months	Sandwiches, dessert
Gruyere	Switzerland	(See Emmenthaler process type)	Appetizer, dessert
Liederkranz	United States	Bacteria, 1–2 months	Appetizer, salads, dessert
Limburger	Belgium, Germany	Bacteria, 1–2 months	Appetizer, sandwiches
Muenster or Münster	Germany	Bacteria, 2–3 months	Appetizer
Mysost (Primost)	Norway	Bacteria, made from whey	Sandwiches, appetizer
Parmesan	Italy	Bacteria, 2 years or more	Grating
Pineapple (a very hard American Cheddar in special form)	United States	Bacteria, 6 months or more	Dessert
Port de Salut	France	Bacteria, 5–6 weeks	Appetizer, dessert
Oka or Trappist	Canada		
Roquefort	France	Mold, 1–5 months	Appetizer, salads, dessert
Romano	Italy	Bacteria	Grating
Sage	United States	Bacteria, flavored sage	Appetizer, dessert
Sap Sago	Switzerland	Bacteria, flavored with clover	Grating
Stilton	England	Mold, 6 months to 2 years	Dessert
Swiss	(See Emmenthaler)		

The Appraisal of Cheese

Nutritive Quality of Cheese

The nutritive quality of cheese can be predicted from the knowledge that the process involved in its manufacture is essentially one of separation of most of the protein and fat of milk from more or less of the water and substances in true solution in it. The amount of heating is such that it results in no more change than that during pasteurization. As would be expected from the nature of the chemical changes associated with coagulation by acid, a cheese made from an acid-coagulated curd, such as cottage cheese, loses calcium in the whey that is retained in the curd in a rennet cheese. Cottage cheese is not a milk substitute so far as calcium is concerned. The principal nutritive losses in the making of Cheddar cheese are the water-soluble vitamins. Any vitamin C left after separation of the whey disappears during ripening, but riboflavin and thiamine may increase as a result of synthesis by microorganisms.[39] (See Table XXIX.)

Cheeses vary extensively not only in content of calcium but also in fat and vitamin A. The vitamin A potency does not strictly parallel the percentage of fat, but skim milk cheeses, such as cottage cheese, and cheeses often made from partly skimmed milk, such as Neufchâtel and Limburger, have the lowest potency. The ripening process itself does not affect the vitamin A value, at least in Cheddar cheese.

Although increased consumption of rennin-coagulated cheeses might well be recommended to supplement adults' calcium intake, the amounts likely to be consumed by children do not represent a practical substitute for milk.

Digestibility of Cheese

The calcium in Cheddar cheese is as well utilized as that from pasteurized whole milk. Cheese contains no roughage and is relatively completely digested; 81 to 94 per cent of the fat and 83 to 97 per cent of the protein is absorbed.

The discomfort which sometimes follows the eating of cheese may be caused in part by irritation of the stomach by the volatile

[39] Dearden et al., *J. Dairy Res.*, 14: 100 (1945). Also Irvine et al., *Sci. Agr.*, 25: 817, 833, 845 (1945).

acids and some of the protein cleavage products developed during ripening. It is probably more often a result of the unsuitable times at which cheese is conventionally eaten, such as at the end of an already sufficient meal. Cheese should be eaten preferably as a substantial part of a meal and in a form which gives some dilution, unless it is used in small amounts almost exclusively for flavor.

Sanitary Quality of Cheese

Because heating milk delays rennin coagulation, manufacturers do not always pasteurize milk used in cheese making unless it is required by state regulations. Although infections incurred through eating cheese are infrequent, several serious outbreaks of typhoid and other diseases carried by cheese have been reported in the United States and Canada in recent years. Cheeses held for ripening at least 60 days are usually safe because pathogens die off, but the period should be doubled if the temperature is below 50 degrees F. (10 degrees C.). This, of course, cannot be applied to the many soft cheeses which do not keep as long as that. The safest procedure is to require pasteurization of all milk used in cheese making. Actually, pasteurized milk makes a consistently higher scoring and better-flavored Cheddar cheese than does raw milk, and one that can be held at a higher temperature and ripened in a shorter period.[40] Pasteurization of milk for cheese making will be more generally required as public health standards rise, although there seems to be no great hazard involved. When the use of pasteurization is in doubt, choosing sharper cheeses helps ensure safety because these have had a longer ripening period during which pathogenic organisms are more likely to die.

Palatability of Cheese

The palatability qualities of cheese, including its flavor, odor, body, texture, and, to a certain extent, its color are related to (1) the types of organisms concerned in its ripening, (2) the length of the ripening period, and (3) variations in the processing before ripening in which curd separation takes place. Even within the same variety of cheese there may be marked differences in these qualities. This may be unintentional and caused by failure to control changes during ripening, or intentional to fit differences in consumer

[40] Fabian, *Am. J. Public Health*, 37: 987 (1947).

preferences. Some desire a cheese with little flavor, and others a cheese with a high flavor. Because the more highly flavored types of Cheddar and some other types require longer curing, they are generally more expensive.

According to grading standards used in the United States, Cheddar cheese of the highest quality is described as having a fine, clean flavor, either mild or aged, and a highly pleasing aroma. Its texture may be close, medium, or open, but the cheese should be smooth and silky, slightly transparent, meaty and waxy, without gas holes. It should be free from cracks or checks and mold. The color may vary in intensity, but it should be uniform.

Economy of Cheese

In food value, 1 pound of American Cheddar cheese approximates 1 gallon of milk, BHNHE figures giving 5 ounces per quart. In more exact terms, cheese of this type is worth about 79 cents per pound in relative nutritive quality when milk sells for 24 cents per quart. Usually American Cheddar cheese is a relatively economical source of the important nutrients of milk for reasons similar to those explaining the relative economy of evaporated milk. The price increases with the amount of ripening. This is a premium paid for higher appetite appeal; there is no significant change in nutritive quality.

One of the economic problems of marketing Cheddar cheese in the ordinary form is the loss resulting from shrinkage and mechanical injury. Most types of packaging are unsatisfactory because they do not prevent mold from developing, and, if tight, they bulge or rip, owing to pressure of CO_2, which is normally evolved. For short-time packaging for sale in self-service stores, cheese can be successfully wrapped in cellophane.

Cooking Cheese

Cheddar and a few other hard cheeses are often heated as in toasted cheese sandwiches, or in blending with other ingredients for sauces, soufflés, fondues, rabbits, etc. When cheese is heated, it softens and develops the consistency of a viscous liquid. The fat tends to separate. If the heating is prolonged, especially at relatively high temperatures, the mass develops toughness and stringiness. Aging improves the cooking quality of Cheddar cheese. This is attributed in part to the increased solubility of the proteins. High-

fat cheeses cook better than low-fat products.[41] Undesirable changes can usually be avoided if the cheese is subdivided by cutting or grating, if the temperature is kept relatively low, and if the time of heating is limited. "Process" cheese presents less of a problem when heated, as will be discussed below.

Process Cheese

American "process" cheese is American Cheddar cheese which may contain not more than 40 per cent water as compared with a maximum of 39 per cent in the original cheese and to which has been added not more than 3 per cent of a suitable emulsifying agent, usually harmless mineral salts such as sodium phosphate. It is made by melting ripened cheese with the emulsifier and pouring it into molds which may be the market packages. Pasteurization terminates ripening by killing the ripening organisms and destroying enzymes. Such cheese remains soft and free from mold until the package is opened. Cheeses of other varieties are also processed.

Although the palatability of process cheese is limited by that of the original cheese, it is agreed, at least by connoisseurs, that the flavor suffers some deterioration in the treatment itself. In cooking, process cheese blends readily with sauces and is less subject to stringiness than the original cheese.

Cheese Foods and Cheese Spreads

Pasteurized process cheese *foods* are similar to process cheese, but have such additional ingredients as dry skim milk, dried whey, or other noncheese ingredients. Pasteurized process *spreads* are similar to cheese foods, but they contain somewhat more water and may include added fruits, vegetables, or meats. These products are, of course, wholesome foods and offer a wide range in flavor, but it is difficult to evaluate them nutritionally on account of their variable composition. In general, if they cost more than the cheapest American or plain process American, one is paying for appetite appeal, not food value.

Besides process cheese foods and spreads, there are on the market a number of mixtures consisting of cream cheese or Neufchâtel cheese with added fruits, vegetables, relishes, or meats. Cream cheese is a soft uncured cheese made from a mixture of cream and some form of milk or skim milk coagulated by souring with or without added

41 Personius et al., *Food Res.*, 9: 304 (1944).

rennet. The finished product contains by federal definition not less than 33 per cent of milk fat and not more than 55 per cent of moisture. Neufchâtel cheese is a similar product containing less fat—20 to 33 per cent—and more moisture—not more than 65 per cent. Both cream and Neufchâtel cheeses may include a limited amount of certain specified gums to bind the water.

Federal standards for food mixtures with a cream-cheese base specify that the total mixture contain not less than 27 per cent milk fat and not more than 60 per cent moisture. The standard for Neufchâtel mixtures specifies a content not less than 20 per cent milk fat and not more than 65 per cent moisture. Neufchâtel mixtures are perishable and require pasteurization to make them keep.

The nutritive value of cream cheese is given in Table XXIX. That of Neufchâtel is somewhat lower in energy and vitamin A on account of its lower fat. As with processed cheese mixtures, it is difficult to evaluate the mixtures based on cream and Neufchâtel types. Since they would ordinarily be used in relatively small servings, their contributions would not be particularly significant anyway. In general, when they cost more than the cheapest American or process American cheese, one is paying the extra amount for palatability qualities.

ICE CREAM AND OTHER FROZEN MIXTURES

The development of commercial manufacture of ice cream dates from about the middle of the nineteenth century. The real period of growth in the industry, however, has been relatively recent, the per capita consumption in 1919, which was 1.37 gallons, increasing to 3.5 gallons in 1949. Data on the consumption of other frozen mixtures or those prepared in the household are not available.

Standards for the composition of ice cream vary from state to state, and consist primarily of a minimum butterfat requirement, varying for plain ice cream from 8 to 14 per cent. In some cases requirements for total solids and weight per gallon are specified. The following figures indicate the usual range of percentages of the different components in commercial products.

Fat	8–20
Sugar	12–17
Milk solids not fat	8–12
Gelatin or gums	0–0.7

The principal types of frozen mixtures are as follows:

Ice Creams

Plain, American, or *Philadelphia* ice cream contains milk products, sugar and flavoring with or without a stabilizer such as gelatin. Plain ice cream is often varied by the addition of such ingredients as fruit, nuts, chocolate, candy, and bread and cake crumbs, the last commonly called *Bisque.* Neapolitan or Harlequin is layered brick ice cream, the layers differing in color and flavor. A small amount of egg (usually dried or frozen) may be added in commercial products to improve their whipping quality. A proposed federal standard for plain ice cream calls for a minimum of 12 per cent milk fat, total solids of 1.6 pounds per gallon, total weight of 4.5 pounds per gallon, and not more than 0.5 per cent gelatin or gums. It is proposed that chocolate ice cream and fruit ice cream be required to have a minimum of 10 per cent milk fat. This reduction as compared to the plain type is to allow for the dilution produced by the chocolate or fruit.

Custard-type ice creams, sometimes called New York or French ice cream, contain milk products, sugar, flavoring, and enough egg yolk to color the product. They may also contain added fruit or nuts. The proposed federal standard for custard-type ice creams specifies a content of 1.5 to 2 per cent egg. Frozen pudding is a custard-type ice cream containing fruits.

Sherbets

Sherbets are frozen mixtures of fruit juices, milk, and sugar, usually containing a stabilizer. The proposed federal standard for sherbets calls for a minimum of 2 per cent milk fat, not less than 8 per cent total milk solids, and a fruit content of 10 to 20 per cent, with no more than 0.5 per cent gelatin or gums, all on the basis of weight. This standard specifies a weight of 6 pounds per gallon.

Ice Milks

Ice milks are low-fat frozen mixtures made from milk, sugar, and flavoring, usually with added milk solids other than fat. They may be either hard- or soft-frozen.

Ices

Ices are frozen mixtures of fruit juices with water and sugar, and usually a stabilizer. Frappés are ices which are frozen to a slushy consistency. The proposed federal standard for ices calls for 10 to 20 per cent fruit and not over 0.5 per cent gelatin or gums.

Mousses

Mousses contain whipped cream, sugar, and flavoring with or without fruits and are still-frozen.

Vegetable-Fat Frozen Mixtures or "Filled Ice Creams"

These are products similar to ice cream except that vegetable fats are substituted for most of the milk fat. Their composition varies and their sale is forbidden in some states to protect dairy interests.

The Structure of Frozen Mixtures

A typical frozen mixture such as ice cream is not a homogeneous solid. The water is never completely frozen. Structurally, when the mixture is considered frozen, it consists of multitudes of tiny ice crystals suspended in a mother sirup of sugar, minerals, and any other components present in true solution in the water. The concentration of these substances in the unfrozen water is so great that its freezing point is too low for further crystallization to occur at the temperatures provided. The ice crystals are mixed with the emulsified fat globules, colloidal particles of milk or milk and egg protein, and the minute air bubbles which have been incorporated by the whipping action of the beater. When gelatin or vegetable gums are present, they form a gel which gives the whole system firmness and a certain amount of resistance to melting. (See Fig. 17.)

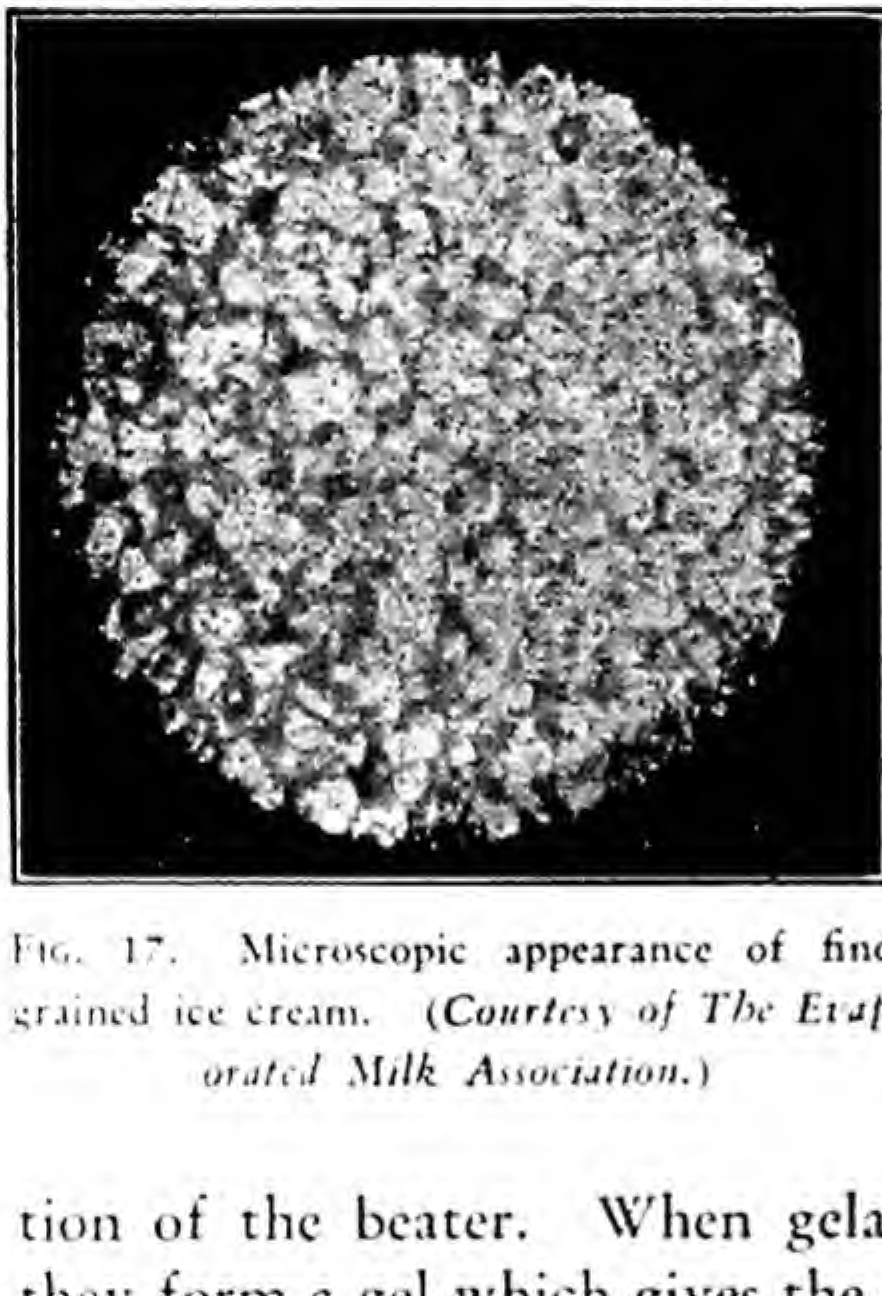


FIG. 17. Microscopic appearance of fine-grained ice cream. (*Courtesy of The Evaporated Milk Association.*)

The Preparation of Frozen Mixtures with Special Reference to Ice Cream

The palatability of frozen mixtures is judged by their texture, body, flavor, appearance, and temperature. *Texture* is determined by the "mouth feel" test and is a product of the interrelationship of size of crystals, temperature, and the lubricating action of fat. Ice cream should be finely granular, not coarse and grainy on the one hand, nor buttery and cloying on the other.

The term *body* is applied to the entire mass or bulk of the frozen product. When ice cream has sufficient body it is firm, but not solid and rubbery, or slushy. It stands up well when removed from the container, but melts gradually. The melted mixture should have the viscosity of a 38 to 40 per cent whipping cream and should not give the appearance of milky water which is characteristic of a melted sherbet.

Five groups of factors control the palatability of frozen mixtures: (1) the ingredients, (2) their treatment before freezing, (3) the conditions under which freezing takes place, such as the time, temperature, vigor of agitation, and the time and temperature allowed for hardening, (4) the conditions under which the frozen mixtures are held, and (5) the temperature at which they are eaten. The management of these factors to secure desirable qualities has been extensively investigated and is summarized in the following discussion.

The Ingredients of Frozen Mixtures and Their Relation to Palatability

The ingredients used in frozen mixtures include milk and its products, nuts, fruits, fruit juices and other flavorings, sugar, eggs, vegetable fats, stabilizers such as gelatin or vegetable gums, and others not of sufficient importance to be considered here.

The Relationship of Composition to Texture. All the solids present interfere to some extent with the formation of ice crystals and consequently tend to result in finer texture. Milk fat, which is supplied in the form of whole milk, cream, evaporated milk, powdered milk, butter, or vegetable fat, interferes with crystal growth and lubricates crystals so that high-fat products seem smoother than low-fat types in which the ice crystals are actually of similar size. Thus when other factors are the same, the higher the percentage of fat, the smoother and more velvety is the texture. Too much fat gives an undesirable stickiness and hardness, but 10 to 18 per cent gives satisfactory products. Homemade ice creams are often made from rich cream which tends to ensure smooth texture even when other conditions of preparation are very unsatisfactory.

Among the milk solids other than fat, the milk protein is important because it stabilizes the milk-fat emulsion. This promotes the formation of many small air cells which are incorporated during freezing and interfere with crystal growth. The proteins are also

hydrophilic and, by binding some of the water, diminish the amount free to freeze. In commercial ice creams, the concentration of non-fat milk solids in the milk and cream is usually supplemented with an additional amount in the form of milk powder or condensed milk.

Both the milk sugar and added sugars promote smoothness by lowering the freezing point of the solution left behind as the water freezes. This, like the binding action of the proteins, prevents part of the water from freezing during either the period of agitation or the period of hardening. The less water there is free to freeze, the more restricted is the growth of crystals and the greater is the apparent smoothness. The amount of added sugar used in ice creams varies from 12 to 17 per cent, whereas sherbets may require from 25 to 30 per cent to sweeten the fruit juices they contain. Sometimes sucrose crystals form in sherbets and result in excessively hard texture. Also, frozen mixtures containing large proportions of added milk solids are supersaturated with lactose. Occasionally lactose crystals form and result in a gritty or "sandy" texture. At least one-fourth of the sucrose in ice cream may be replaced by dextrose (corn sugar) without impairing palatability, but a larger proportion of dextrose may result in both lessened sweetness and a lowered freezing point, which makes freezing under household conditions difficult.

The stabilizers, gelatin and vegetable gums, influence texture, not by any protective action such as they have in emulsions, but by binding part of the water and by forming a gel structure which holds the crystals in its meshes and probably hinders their growth during hardening. One-half of 1 per cent of gelatin is sufficient for this purpose; it is so effective in reducing the chances of obtaining a coarse product that it is commonly added to commercial ice cream mixes. More than 1 per cent of gelatin may be considered an adulterant from the consumer's point of view.

A stabilizer is not so essential in the homemade product, especially in one that is high in fat, because homemade ice cream is usually consumed so soon after freezing that there is no time for excessive growth of crystals. Eggs or cooked starch pastes also tend to increase smoothness in ice cream. Sherbets, because of their low fat content, are especially likely to be coarse if gelatin, vegetable gum, or egg is not added.

The Relationship of the Composition of Frozen Mixtures to Body. Substances added to frozen mixtures to improve the body are called "fillers." They include egg yolk (fresh, frozen, or dried),

cream with a high fat content, and additional milk solids in the form of milk powder or concentrated milk. Wheat or rice flour, or cornstarch, may be cooked and added when the fat content is low, but if these are present to any considerable extent flavor is injured, swell is reduced, and the body is too heavy. They are not used commercially except in concentrated mixes for household use. Homemade ice creams usually contain less filler other than fat and consequently have less body than is considered desirable in the commercial product.

The Relationship of the Composition of Frozen Mixtures to Appearance. Consumers consider color a very important quality in the appearance of frozen mixtures. They prefer Philadelphia ice cream that has the yellow tinge characteristic of rich cream. When fruit flavors are used in either sherbets or ice cream, the color should be that characteristic of the fruit and not so pale that a dilute concentration of the fruit is suggested.

The Relationship of the Composition of Frozen Mixtures to Flavor. The flavor of frozen mixtures is influenced especially by the fat content, acidity, salt, sugar, and such added flavoring substances as vanilla, spices, chocolate, caramel, and fruits. All flavoring substances should be of high quality. Fresh fruits should be thoroughly ripe. Frozen fruits compare favorably with the fresh, and some canned and dried fruits may be used successfully. Honey may be substituted for all or a part of the sugar in ice cream with a pleasing variation in flavor.

The relationship of consumer preferences to the composition of ice cream has been tested by selling that prepared with different proportions of certain ingredients to the same persons over a period of days. Experiments with varying proportions of fat (18, 15, and 12 per cent), sugar (19, 16, and 13 per cent), milk solids nonfat (12.9 and 6 per cent), and gelatin (1, 0.5, and 0 per cent) demonstrated that there was a decided preference for the richest, sweetest, and firmest products.[42] Both flavor and body preferences may be controlled by serving temperature.[43] For example, in a series of mixes in which the sugar varied from 12 to 18 per cent, those with the higher proportions were too sweet at high serving temperatures [12 and 16 degrees F. (−11 and −8.8 degrees C.)] but desirable

[42] Williams and Campbell, *U. S. Dept. Agr., Bull.* 1161 (1923).

[43] Reid et al., *Mo. Agr. Expt. Sta. Res. Bull.* 323 (1940).

at low serving temperatures (8 degrees F.; −13 degrees C.). This is a result of the diminished sensitivity to sweetness of the taste buds at low temperatures.

Preliminary Treatment of the Ingredients of Frozen Mixtures and Palatability

In household preparation of frozen mixtures, the ingredients are usually combined and frozen immediately. In the making of mousses the cream is whipped before mixing. Under conditions of commercial manufacture, ice cream mixes are customarily pasteurized to promote solution of ingredients and to destroy pathogenic bacteria and organisms conducive to spoilage. Homogenization is then employed because it prevents churning of the fat and increases fineness of texture of the frozen product. Fineness of texture results from increasing the number of fat globules; probably both their interfering action on crystal growth and their lubricating power in the mouth are extended. Also, because homogenization lowers the whipping capacity of the mix, the air cells incorporated during freezing are smaller. Holding for several hours, a process known as aging, is a frequent practice. This results in the blending of flavors and improves whipping quality.

Conditions under Which Freezing Takes Place and the Palatability of Frozen Mixtures

The freezing points of these mixtures are below that of water. Sugar is the principal ingredient responsible for this depression. Most ice creams begin to freeze at −2 to −5 degrees C. (28.4 to 23 degrees F.); sherbets freeze at −4 to −5 degrees C. (24.8 to 23 degrees F.). A household ice-cream freezer is constructed so that heat may be withdrawn from the mix by surrounding its container with a freezing mixture, usually ice and salt. The relationship of the proportion of salt to the freezing points of ice-salt mixtures was shown in Fig. 2. Commercially, ice cream is frozen continuously in mechanical freezers.

As everyone knows, when water is still-frozen, a solid lump of ice forms. If it is beaten while being frozen, an icy mush consisting of large lumps results. In ice cream, the components other than water decrease the size of the crystals, but any mix except one high in fat or stabilizers is coarse and unpalatable if frozen without agitation. Agitation favors the formation of many small crystals. To produce it, an essential part of the freezer is the dasher, which scrapes crystals

off the sides before they become large and coarse, aids in the rapid transmission of heat, and incorporates air in small bubbles. As previously discussed, air bubbles prevent crystal growth and thus promote smoothness. High percentages of egg, fat, and other milk solids assist in the formation and stabilization of the foam structure.

During freezing, the mixture expands, owing partly to the increased volume of the water as it changes to ice, but more to the incorporation of air. The increase is known as *swell* or *overrun*, and desirable texture and degree of lightness are associated with a definite amount of such expansion. In a study of consumer preference for commercial ice cream, overrun of 76 to 92 per cent was favorably received.[44] Under commercial conditions of manufacture, more than 100 per cent overrun may be developed, but amounts above this figure constitute adulteration with air from the consumer's standpoint and can be controlled by legalizing a minimum weight of 4½ pounds per gallon such as the federal government employs in its purchases. Under household conditions, only about 35 per cent swell is common, but the freezer should be filled only about two-thirds full and other factors controlled to obtain about 50 per cent if possible. Commercial sherbets and ices usually overrun 35 to 40 per cent; more gives a fluffy, coarse product.

The amount of air which is incorporated depends primarily upon the temperature, the composition of the mix, and the rate and time of turning the freezer. If the ice-salt mixture is too cold, the mix may freeze before there is time to incorporate sufficient air. When the freezer is manipulated by hand, energy should be conserved by slow turning at first because little air is retained before the mix is cooled to about 26 degrees F. (3.3 degrees C.). From this point on, turning should be rapid and continuous until it becomes difficult. One part of salt to 8 of ice by measure makes a satisfactory freezing mixture.

When the proper amount of swell has been developed, only a portion of the water in a frozen mixture has crystallized. In ice cream, the proportion of the water changed to the solid state varies from 15 to 30 per cent at this stage. Additional crystallization takes place, however, as a result of still freezing during further holding which is known as the hardening period. This stage may be carried on by packing the container in a colder ice-salt mixture than was used during agitation or by placing it in a deep freezer or cold

[44] Grumbine and Halliday, *Food Res.*, 3: 653 (1938).

storage room at 0 degree F. (-18 degrees C.), or lower, the latter being common commercial practice. Hardening may continue until about 70 per cent of the water has changed to ice, but freezing can never be complete because of the increasing concentration of solutes in the remaining sugar solution as ice is formed.

If whipping is discontinued too soon, so much water remains to be still-frozen that coarseness results, because the tendency during still freezing is for crystals already formed to increase in size rather than for nuclei to form. Slow hardening or thawing and subsequent refreezing are also likely to have this result. In fact, any change in temperature alters the ice-water equilibrium, and shifts in either direction may alter texture.

Conditions of Holding in Relation to the Palatability of Frozen Mixtures

Under commercial conditions especially, conditions of holding are important because such products as ice cream may be stored for weeks. As indicated above, a relatively constant low temperature [preferably at 0 degree F. (-18 degrees C.)] is essential to prevent the thawing and refreezing which produces coarse crystals. The development of oxidized flavor is a problem of storage of ice cream.

Serving Temperature and the Palatability of Frozen Mixtures

Texture and body characteristics of frozen mixtures and sensations involved in experiencing flavors are affected by the temperature at which such products are served, as previously explained.

Still-frozen Desserts

Creams, sherbets, and ices, frozen without continuous agitation may have acceptable texture, especially if they are high in fat, contain cream, egg white, or evaporated milk, which have been previously whipped, or include a suitable stabilizer. Mousses are most satisfactory for such conditions of preparation. A mixture of three parts of ice to one of salt makes a suitable freezing medium. If a mechanical refrigerator is used, the control should be set for the lowest temperature. Removing mixtures which do not contain whipped cream from the refrigerator for a quick whipping once or twice during the freezing period improves texture. Cutting down the sugar in the mixture to be frozen makes the mixture easier to freeze because large proportions of sugar lower the freezing point. However, too

small a proportion of sugar may allow the mixture to become excessively hard. The sweetness may be supplemented as desired by serving sweet sauces with the dessert.

Tests of different stabilizers in refrigerator ice creams containing only 10 per cent of fat made from mixtures of skim milk, whipped cream, sugar, and flavoring indicate that agar used in combination with dried skim milk produces the best texture and flavor.[45] Pectin produces a desirable texture but a typical flavor which might not always be appreciated. Gelatin gives a coarser texture than either pectin or agar. Cornstarch and dried skim milk mask the flavor somewhat but they, along with chocolate, corn sirup, and increased sugar, have some stabilizing action. Sherbets and ices may also be still-frozen. Gelatin or beaten egg white makes a satisfactory stabilizer.

Commercial ice cream mixes which contain part or all of the ingredients except water are available for still freezing in the household. They have the advantage of utilization of a wide range of stabilizers not generally available on the retail market, hence they make smooth-textured products. Because agar and some other stabilizers form gels which do not re-form after they are broken, the direction, "Do not stir," appears on some products.

The Appraisal of Frozen Mixtures As Food

The nutritive values of average commercial ice cream and sherbet are given in Table XXIX. Although both ice cream and sherbet have some of the nutrients of milk, the nutrients are diluted with sugar. It takes about 2 quarts of ice cream to equal the protein and calcium values of 1 quart of milk. Mousses contain a high proportion of fat calories in relation to other nutrients, and ices, of course, furnish primarily sugar calories. Ice cream is somewhat better balanced than most other sweet desserts, but all these foods must be limited to make room for more nutritious foods, especially in the diets of children and of adults having low energy requirements. Vitamins do not appear to be inactivated by freezing in these products, nor does freezing reduce absorption of calcium and phosphorus or alter digestibility.

Iced milk has the nutritive values of milk plus about 60 calories of added sugar for each 100 calories of milk products. On account

[45] Bentley and Watts, *Food Res.*, 4: 101 (1939).

of its relatively low fat content, it can compete favorably with ice cream on a cost basis.

Vegetable fat "ice creams" are similar to ice cream in nutritive values except for the relatively low content of vitamin A resulting from the substitution of vegetable fat for milk fat. These products can be priced much lower than true ice cream, often being sold for little more than half the price of the latter. Flavors of vegetable fat products are being improved to the point where their acceptability also makes them highly competitive with ice cream.[16]

The maintenance of high sanitary quality in frozen mixtures, especially those containing milk products, requires very careful handling. Ice creams are suitable media for the development and survival of many types of bacteria, including the common pathogenic forms associated with milk-borne diseases. The equipment with which the mix or any of the ingredients come in contact may, of course, become a source of contamination. Epidemics of typhoid fever, septic sore throat, diphtheria, scarlet fever, dysentery, and gastrointestinal disturbances have been attributed to ice cream. Neither the original freezing nor refreezing after thawing kills pathogenic bacteria. As a matter of fact, the bacterial count of ice cream held at 14 degrees F. (− 10 degrees C.) may increase.

High bacterial counts in frozen desserts may be caused by the use of contaminated ingredients (milk products, nut meats, coloring, fruits, and gelatin), particularly when these are not added until after pasteurization of the basic mix, by the complete absence of pasteurization, by improper pasteurization with or without aging too long or at too high a temperature, or by the use of contaminated equipment. When ice cream is purchased from bulk packages, the dipper used by the retailer represents a special hazard. Diseased and unsanitary workers may also infect the product.

As in milk, a high bacterial count in ice cream does not always indicate an unsafe product, nor a low count a safe one, but the size of the count is a measure of the relative care with which it has been handled. Some states have established minimum bacterial standards running up to 500,000 per gram, but the federal government specifies not more than 50,000 per gram in the products that it buys. In addition, laws should require pasteurization of the mix and equivalent treatment of all ingredients added later. Not all states have such requirements at present. Sanitary inspection of plants

[16] Tobias and Tracy, *Ice Cream Rev.*, 36: 112 (1952).

and retail stores is also essential to ensure against hazard to consumers. The fact that bulk ice cream tends to be higher in bacterial count than that packaged in the factory demonstrates the contaminating influence of dipping in the retail store. Partly because pasteurization of the mix is not employed in making frozen desserts in the household and because raw milk and cream are often used, their bacteriological quality is variable and may be inferior to that of many commercial products.

Other possible causes of high counts in homemade products are inadequate sterilization of equipment, seepage of melted ice into the can, and careless packing after the dasher is removed. Refrigerator-frozen desserts tend to be lower in count than those frozen with agitation. Again, it is not possible to evaluate the significance of the bacterial count in a particular product without knowing the kind of bacteria involved, but at least it is well to remember the limitations of freezing in removing pathogenic hazards in foods of this type and the points at which care should be taken to eliminate or to avoid contamination.

When ice cream was sold at $1.25 per quart, which was the price in the early days of its production, it was a luxury. The efficiency of modern methods of commercial manufacture has lowered its price considerably, but the costliness of cream itself when bought at urban prices makes even a homemade product relatively expensive. The homemade milk sherbets make palatable and relatively economical desserts. Because the fat is the most expensive ingredient of ice cream and because it is not needed in high concentration for nutritional reasons, it is not to the advantage of consumers to set minimum standards for the fat content of ice cream as high as those in some states. Consumer interest is best served by an enforced minimum which guarantees the obtaining of what is paid for, but the level of this minimum need not be high for nutritional reasons.

Another factor in the relative economy of different samples of commercial ice cream is the weight in relation to the volume of the package, because sales are made according to volume. This is affected by the proportion of overrun and by the pressure used in packaging. Owing to the force employed to fill the package at the store and perhaps to shrinkage in the bulk container, bulk ice cream with an overrun of 90 per cent at the factory may average only 40 per cent when delivered to the consumer. This is the reason that prepackaged ice cream is sometimes cheaper but considered less

palatable. In a study in which 42 pint samples of ice cream were purchased and weighed, the range in weight was from 208 to 480 grams (about 7 to 15 ounces).[47] Bulk ice cream packed at the store weighed more on the average than that packaged at the factory. As would be expected, variation in weight was greater among pints packed by the retailer, but the same brand of factory-packaged product varied as much as 62 grams (about 2 ounces) among 7 samples. If the federal specification of 4½ pounds per gallon were established as a minimum standard of weight, pints would be required to weigh at least 9 ounces.

SUMMARY OF POINTS TO CONSIDER IN CHOOSING MILK AND ITS PRODUCTS

1. Milk and its equivalent products are of such great importance in obtaining nutritional balance in the average American pattern of eating that special effort should be exerted to safeguard their share in the food budget. They are indispensable for calcium and nearly so for riboflavin, and furnish important amounts of most essential nutrients. Adults and children up to the age of 10 should have at least 1½ pints of milk per day, and older children and youths to the age of 20, at least 1 quart.

2. The sanitary quality of milk should always be safeguarded by heating at least to pasteurization temperatures.

3. Reconstituted evaporated milk is an approximate equivalent of whole milk and is nearly always available at a substantial saving in cost. It can be used in cooked foods without objectionable effect on flavor and, if not diluted, is valuable to fortify the diet with the nutrients of milk in concentrated form.

4. Skim milk in either fluid or dry form is a very economical source of the calcium and riboflavin of milk together with its proteins and other nutrients except vitamin A and fat calories. In dry form it may be used without full dilution to fortify milk or foods containing milk. Unless children receive daily a source of vitamin D which also contains vitamin A, it is safer to give them the recommended amounts of whole milk, but adults may substitute skim milk for whole milk if they eat liver once a week or make up the vitamin A thus lost by eating extra green and yellow vegetables. Buttermilk is similar to skim milk in food values.

[47] Grumbine and Halliday, *Food Res.*, 3: 653 (1938).

5. Cottage cheese is an economical source of protein, but is not a milk substitute in calcium and riboflavin. American Cheddar cheese of the least expensive types (mild or processed) is a comparatively economical source of the calcium and protein of milk and might well be used in larger amounts than at present.

6. Cream and ice cream are comparatively expensive sources of the important nutrients of milk.

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CHAPTER 11

EGGS

The structure and composition of eggs.
The appraisal of eggs as food.
Frozen eggs.
Dried eggs.
The cooking of eggs and egg mixtures.
  Cooking eggs.
  Cooking food mixtures containing eggs.
  The appraisal of cooked eggs.
Summary of points to consider in selecting and using eggs.

Hen's eggs are most universally used for food, but those of turkeys, guinea fowls, ducks, and geese are often consumed. To a limited extent, the eggs of wild birds make a contribution to the local dietary in some places. Fish eggs and turtle eggs are examples of eggs other than those of birds which have served culinary purposes.

Per capita consumption of eggs has been rising; it rose from 35.2 pounds in 1918 to 48.2 pounds in 1948.[1] This latter figure is the equivalent of 36.7 dozens of medium eggs, or a little over 1 egg per person per day.

THE STRUCTURE AND COMPOSITION OF EGGS

Hen's eggs weigh from 40 to 60 grams. Of this, the shell and its membranes form 5 to 8 grams, the yolk 12 to 18 grams, and the white 23 to 34 grams. The edible portion of a medium egg averages about 44 grams—the white about 28 grams, and the yolk about 16 grams.

The yolk is made up of concentric layers of yellow yolk separated by thin layers of white yolk. The germinal disk, where growth begins when conditions are suitable if the egg is fertile, moves outward with the addition of each layer during the formation of the egg and finally appears as a light-colored spot on the surface of the yolk.

[1] *U.S.D.A. Misc. Pub.* 691 (1949).

The yolk is enveloped by four layers of white. The first layer is most dense and is continuous with the chalazae, two tough strands of white that hold the yolk in free suspension. It makes up the smallest proportion of the total white. Next to this viscous inner layer of white is a second which is thin and fluid. This layer is encircled by a third which is jellylike and constitutes a little over half of the total bulk of all the layers. An outer layer is watery and trans-

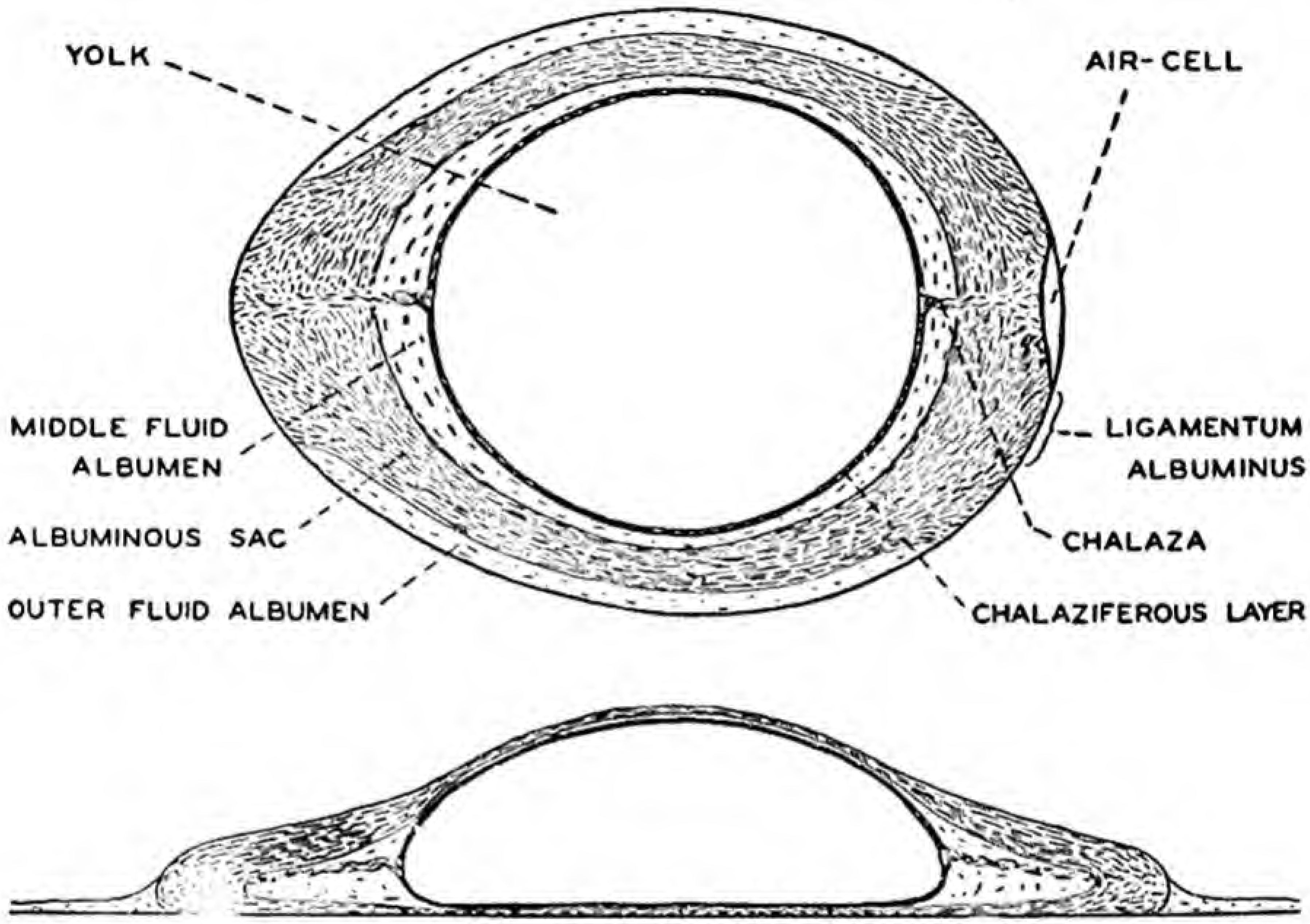


FIG. 18. Diagram of gross structure of an egg. (Romanoff, *Food Research*, 8: 286, 1943. *Courtesy author and publisher.*)

parent.[2] In most investigations of its qualities, white of egg is divided into only two layers, a thick and a thin, because this is the only fractionation which is practicable.

The amount of total solids in thin white varies little from that in thick white. In fact, the middle thin layer contains a slightly larger proportion of dry matter and protein than the middle thick portion. The difference between the two is probably a matter of colloidal structure. The proportion of thick to thin white varies somewhat from egg to egg and is markedly affected by age of the egg and holding temperatures. The entire egg contents just described are enclosed within two shell membranes and the shell. The shell bears an outer gelatinous coating which may be readily removed with water.

[2] Romanoff, *Food Res.*, 8: 286 (1943).

The egg when first laid is completely filled but when cooled the contents contract, and an air space is formed between the two shell membranes. This is usually located at the large end of the egg, and is less than 1/8 inch in depth when first formed. When the egg is kept for a time, evaporation of water from the egg contents causes the air cell to increase in size. Figure 18 shows the gross structure of an egg.

The white of egg is a colloidal dispersion of proteins, mostly albumin, in water. (See Table XXXV.) The yolk consists of several proteins, similarly dispersed, but mixed with an emulsion of the egg fat. Ash constituents and vitamins are found in solution in both yolk and white.

Table XXXV. The composition of hen's eggs

[Data from Chatfield and Adams *]

	Water	Protein	Fat	Ash
Whole egg	74.0	12.8	11.5	1.0
Yolk	49.4	16.3	31.9	1.7
White	87.8	10.8	0.0	0.6

* Chatfield and Adams, *U. S. Dept. Agr., Circ.* 549 (1940).

THE APPRAISAL OF EGGS AS FOOD

The term "new-laid" is applied to eggs which have not been held for any considerable period to distinguish them from "fresh" eggs, which are defined variously in different states and are sometimes merely those that have not been subjected to cold storage. New-laid eggs have not undergone any of the changes associated with holding or processing. So long as eggs are edible, the principal changes affect palatability and will be discussed under that topic.

Nutritive Quality of Eggs

The natural function of eggs would lead one to anticipate that they contained a suitable mixture of nutrients for animal growth. The nutritive contributions of whole eggs and yolks and white are shown in Table XXXVI.

Eggs are significant sources of complete protein, iron, calcium, and vitamins A, D, thiamine, and riboflavin. Studies of the nutritive value of the proteins of eggs show that they are adequate for growth, reproduction, and lactation. In fact, they are so well

Table XXXVI. The nutritive contributions of eggs, given as percentages of the *Recommended Allowances* for a physically active man

[Babcock, *N. J. Agr. Expt. Sta. Bull.* 751 (1950)]

Food, measure and description	Food nutrients: Energy	Protein	Calcium	Iron	Vit. A	Thiamine	Riboflavin	Niacin	Ascorbic acid
1 whole medium in shell, 2 oz. (54 grams)	2½	8½	2½	11	11	3½	8	(0)	(0)
1 white medium, 1.1 oz. (31 grams)	½	4½	(0)	1	(0)	(0)	4½	(0)	(0)
1 yolk medium, 0.6 oz. (17 grams)	2	4	2½	10	11	3½	3½	(0)	(0)

adapted to animal needs that they are often used as the standard of comparison for biological values of other proteins. Also they are very valuable in bringing to full nutritive efficiency proteins of other foods which, when fed by themselves, are not so efficient, the cereal proteins for example.

The most important mineral contribution of eggs is iron, since most of the calcium is in the shell. Practically all the iron is found in the yolk and is at least as efficiently used as that in any other food. It has been suggested that the high calcium content of egg shells could be made available for human consumption, in dried eggs at least, by fine grinding and addition to the powder.[3] The mineral content of eggs is not closely related to the amount in the feed of the hen. This has been shown by experiments in which it was not possible to alter the iron or calcium percentages in eggs by varying the amounts of these constituents in the diet of the hen.

The vitamin A value of the eggs is present exclusively in the yolk. As in milk, the intensity of the yellow color of the yolk is not directly related to its vitamin A potency because it contains the intensely colored provitamins as well as the pale-colored vitamin, and also because the principal pigment in eggs is xanthophyll, a substance which is not transformed to vitamin A. Thus pale-colored yolks from hens fed with cod-liver oil may have high potency. But, because most feeds containing xanthophyll (green leaves and yellow) also contain provitamins A, deeply colored yolks *usually* have a high vitamin A value. The vitamin A potency of eggs is affected by the amount in the food of the hen, as is true of milk. Market eggs in

[3] Dawson et al., *Food Res.*, 12: 288 (1947).

the summer average higher than winter eggs produced when rations have less vitamin A value.

Eggs are one of the few natural foods which contain a significant amount of vitamin D. The quantity present varies with exposure of the hen to sunlight and the vitamin D content of the feed. Since eggs from hens on rations which included 2 per cent sardine oil (approximating standard cod-liver oil in vitamin D potency and as high a level as it is practical to feed either oil) have been found to contain 22 USP units, this probably represents as high a level as can ordinarily be expected. The National Research Council recommends 400 USP units of vitamin D per day for infants and children until growth is complete, and for pregnant and lactating women. Hence eggs cannot be considered a substitute for more potent antirachitics for these groups.

The white contains a substantial proportion of riboflavin but only traces of thiamine. The amounts of thiamine and riboflavin in eggs have been found to be affected by the potency of the rations in these constituents. Riboflavin may frequently be so low that hatchability of the eggs is inferior, but, in ordinary feeding practice, whole grains and other grain feeds probably furnish adequate supplies of thiamine.[4] Eggs contain no vitamin C and only an insignificant amount of niacin.

The addition of eggs to a diet for children which was believed to be already adequate has been found to result in improvement in health and in increased hemoglobin content of the blood.[5] Both iron and copper and probably an unknown third factor were believed to be responsible for the value of the egg. Thus, eggs seem to be similar to milk in having the capacity to supplement the usual human dietary and to supply so many essentials that any serious shortage is less likely to occur when they are included. In the amounts in which they were eaten by city families in 1948, they contributed 2.6 per cent of the energy, 7.3 per cent of the protein, 2.7 per cent of the calcium, 8.2 per cent of the iron, 6.7 per cent of the vitamin A, 2.9 per cent of the thiamine, and 7.2 per cent of the riboflavin consumed.[6] Thus the primary contributions of eggs are iron, protein, vitamin A, and riboflavin.

During the period that eggs remain edible, storage appears to have no significant effect on their nutritive quality so far as the nutrients

[4] Cruickshank, *Nutr. Abstr. & Revs.*, 10: 645 (1941).

[5] Rose and McCollum, *J. Biol. Chem.*, 78: 549 (1928).

[6] *U. S. Dept. Agr., Misc. Pub.* 691 (1949).

considered in this book are concerned. The major change is a small decrease in protein value.[7]

Digestibility of Eggs

Raw egg white, when well beaten, is fairly completely digested by human subjects, about 85 per cent of the protein being absorbed. Unbeaten raw white is not so well absorbed, perhaps because its viscosity prevents penetration by digestive enzymes, and because of the presence of an antienzyme. The raw white leaves the stomach very rapidly, but the whole egg or the yolk passes on much more slowly, probably because of the greater fat content of the yolk. Despite a once popular belief, there is no evidence on which it is legitimate to base a recommendation for the eating of raw eggs. As is true of nutritive quality, storage of eggs has not been shown to affect digestibility.

Sanitary Quality of Eggs

New-laid eggs usually contain few if any bacteria. Hens and especially ducks may occasionally be carriers of *Salmonellae* (pathogenic bacteria), however, and infect the eggs and through them foods with which they are mixed. In one study it was found that about 3 per cent of the samples of hen's eggs tested carried these organisms.[7a] They have been responsible for outbreaks of food poisoning.[8] Infected raw eggs as used in mayonnaise are most likely to be involved, but the temperatures reached in cooking may not be sufficient to kill *Salmonellae* in some other foods.[9]

Cool storage at all times reduces chances of shell penetration.[10] If the shells are washed before breaking and if any product in which the eggs are incorporated which does not reach pasteurization temperatures in cooking is held in a refrigerator, the hazard is small.

Blood spots and meat spots in eggs come from the oviduct of the hen and do not indicate spoilage or unwholesomeness of the egg.

Palatability of Eggs

A new-laid egg has a characteristic appearance when opened. The yolk is almost spherical, owing to the strength of the vitelline mem-

[7] Evans et al., *Poultry Sci.*, 28: 206 (1949).
[7a] Carter et al., *Pub. Health Repts.*, 65: 778 (1950).
[8] Watt, *Pub. Health Repts.*, 60: 835 (1945).
[9] Clarenburg and Burger, *Food Res.*, 15: 340 (1950).
[10] Wolk et al., *Food Technol.*, 4: 316 (1950).

brane. The germinal disk appears as an indistinct spot. The color of the yolk is uniform, not mottled, and varies in intensity from a light yellow to a deep orange. The yolk color is due to the presence of carotenoid pigments, especially xanthophyll, which are derived from such feeds as corn and green leaves. Seasonal variations in amount of color are caused by variations in the amount of green feed. Yolk color is an important factor in market preferences for eggs, New York consumers choosing those with pale yolks, whereas average consumers elsewhere prefer those which are neither pale nor dark. Sometimes, especially in the spring, eggs are produced which have olive-colored yolks and which are known as grass eggs, alfalfa eggs, or green rots. This unnatural color and the strong flavor accompanying it injure the eggs for culinary purposes. The difficulty is often caused by the eating of plants belonging to the mustard family. Cottonseed meal as a feed also produces olive-colored yolks, but the color becomes bright yellow when the egg is cooked.

In a new-laid egg, the inner, most dense layer of white is scarcely visible, and the chalazae are very firm. The middle thick layer is jellylike, merging gradually into the watery outer layer. However, the proportion of thin white in a new-laid egg varies so much that some fail to qualify for Grade A. The white in a new-laid egg is normally colorless and somewhat cloudy.

The contents of a new-laid egg should have little or no odor other than a slight smell of lime. Not only plants of the mustard family, mentioned previously, but other feeds may contribute strong, objectionable odors and flavors to eggs. Fatty acids may be absorbed and laid down in the yolk without change and when these come from fish meal of inferior grades, they sometimes carry with them substances which impart a fishy flavor to the yolk.

Changes Which Take Place When Eggs Are Held. Although new practices of poultry management are resulting in more general year-round egg production and a decrease in the amount held in cold storage, nearly one-half of the total egg crop of the year is still produced during the 4 months, March, April, May, and June. This unevenness of supply would lead to periods of flooding the market followed by periods of scarcity and prohibitively high prices, if the flow to the market were not modified by storage. The factors involved in the holding of eggs thus become of interest to every consumer.

Even when eggs are held for but a few hours, certain environmental conditions can produce very undesirable changes. The

changes which may develop when the egg is held and which in time result in "stale" eggs, or in some cases inedible eggs, are outlined below:

1. Loss of water by evaporation results in the formation of a large air cell and in the weakening of the structure of the egg. The size of the air cell is not by itself a very satisfactory measure of egg deterioration.
2. Passage of water from the white to the yolk produces a more fluid yolk and stretches the vitelline membrane so that it breaks easily. This causes difficulty in separating yolks from whites and permits spreading of the yolk into the white if the egg is carelessly handled. The change can be followed by measuring the "yolk index," or the relative proportions of yolk and white.
3. Change of the thick white to a fluid condition which is described as watery white is probably caused by the action of a proteolytic enzyme. The percentage of thick white is considered one of the best indicators of egg quality.
4. Actual decomposition caused by bacteria or molds.
5. Acquisition of off-flavors.
6. Partial development of the embryo.

The modern cold storage process, as applied to eggs, has been developed to aid in the prevention or retardation of the changes which tend to take place when eggs are held. Evaporation is diminished by the low temperature [about 29 degrees F. (-1.67 degrees C.)] of the storage rooms and by high humidities, which may be artificially produced and maintained. The passage of water from the white to the yolk is much less rapid at the low temperature of cold storage than at room temperature.

Change in the fluidity of the white is more difficult to control, but it is likewise retarded by cool temperatures. Prevention of loss of the original carbon dioxide content of the eggs by increasing the concentration of this gas in the atmosphere of the storage space delays formation of "watery whites." The loss of carbon dioxide in eggs is associated with a decrease in hydrogen-ion concentration of both whites and yolks as storage proceeds. Fresh egg white has a pH of about 7.9, storage egg white of 8.9 or more, fresh yolk 6.3 or less, and storage yolk as high as pH 7. When eggs are buried in oats, a method of storage common in rural communities, the respiration of the oats increases the carbon dioxide concentration in the surrounding air.

Actual decomposition of eggs during storage is reduced by choosing only clean, new-laid eggs for holding. This minimizes the chances for contamination, and the low temperature retards development of microorganisms, so that the eggs will keep for many months.

Although washing in itself does not cause eggs to deteriorate, it tends to increase the probability of their becoming infected from the dirt on the shell and is not generally considered desirable in the case of eggs which are to be stored. The acquisition of off-flavors is not a serious problem when the storage rooms are kept free of odors and when the eggs are held in new cases with white pulp fillers instead of the strawboard fillers formerly used, which contributed the flavor associated with storage eggs in the early days of the process.

A partial development of the embryo is prevented either by holding only infertile eggs, or by cooling fertile eggs to at least 68 degrees F. (20 degrees C.) immediately after they are laid. The development of the embryo may begin at temperatures above this, and later at subincubation temperatures [68 to 103 degrees F. (20 to 39.4 degrees C.)] death is likely to occur and decomposition to set in. March and April eggs are usually superior to late summer eggs when both are taken from storage in January, because there has been less chance of incipient incubation in the former, and because the interior quality (amount of thick white, for example) of the eggs of some hens decreases as the laying season advances.

Eggs which are to be placed in cold storage are often coated with a tasteless, colorless, mineral oil. This closes the shell pores and helps preserve quality by reducing absorption of environmental odors, evaporation, and loss of carbon dioxide.

In the household, eggs should always be held in a refrigerator. They can lose as much of the fresh qualities in 3 days at room temperature as in 2 weeks in a refrigerator. They should not be washed until just before use. Placing with the large end, where the air cell usually is located, up prevents the pressure of the weight of the egg from forcing it upward, thus loosening the shell membranes. Also, the yolk, being lighter in weight than the white and tending to rise to the top, is more likely to adhere to the membrane and break when the shell is opened if the small end is up. Storage in a tight container, instead of a wire basket, reduces evaporation and contraction of environmental odors.

Household preservation of eggs for longer periods in the shell include shell treating with oil, submerging in water glass, and pasteurization. For oil dipping, new-laid eggs (those not over 8 hours

old) are dipped in white mineral oil at 70 to 90 degrees F. (21 to 32 degrees C.), drained, and placed small end down in clean jars or other containers. The cooler the storage place the better—not under 32 degrees F. (0 degree C.) nor over 65 degrees F. (18 degrees C.). Under these conditions the eggs remain in excellent condition for 3 months and are edible for 5 months.

Home preservation of eggs in water glass involves submerging them in a solution of commercial water glass (sodium silicate) and water. This solution prevents evaporation, loss of CO_2, contamination, and absorption of odors. The container should be kept in a cool place, not higher than about 55 degrees F. (12.8 degrees C.); if possible, even lower.[11] The fresher the eggs, the better they are for water-glass storage. Packing them when only a few hours old, thus retaining their CO_2, is desirable. At the end of as many as 10 months, the principal changes in appearance will be a slightly darkened yolk, which is somewhat flattened because the vitelline membrane has weakened, and a slightly watery white, frequently tinged with pink. This is caused by iron which has diffused from the yolk.[12] Whipping quality is somewhat inferior to that of fresh eggs as is true of all eggs with thin whites. The deposition of silica in the shell tends to seal the pores so that the steam formed on the interior when the eggs are boiled bursts the shell, unless it has been previously pricked. As in storing by any other method, success depends upon the quality of the egg when storage begins.

Eggs may be pasteurized by holding in water at 130 degrees F. (54.4 degrees C.) for 15 minutes, or in boiling water for 5 seconds. In a test with eggs processed by the low-temperature pasteurization followed by shell coating with oil, it was found that they might be stored at room temperature for as long as 6 months. The heat treatment stabilizes the white, kills bacteria, and checks embryo development. When eggs pasteurized by the second method are refrigerated, they remain edible for 12 months.[13]

Quality changes which develop after eggs are removed from cold storage follow the same pattern, regardless of length of time they have been in storage. Nonstorage eggs and storage eggs of the same quality when removed from storage deteriorate at about the same rate if they are held under similar conditions.

[11] Hall, *Poultry Sci.*, 24: 451 (1945). Also Romanoff, *Poultry Sci.*, 27: 369 (1948).

[12] Bandemer and Schaible, *Poultry Sci.*, 25: 453 (1946).

[13] Romanoff and Romanoff, *Food Res.*, 9: 358 (1944).

Grading Eggs. The market quality of eggs is judged by the appearance of the shell and of the contents when viewed by strong transmitted light in a process which is called candling. (See Fig. 19.) Candling reveals the depth and regularity of the air cell and the size, position, and mobility of the yolk, as well as the degree of firmness and clearness of the white. These factors are indicators of the holding changes in the egg. The presence of rot, mold, or embryo development is also revealed. When new-laid eggs are

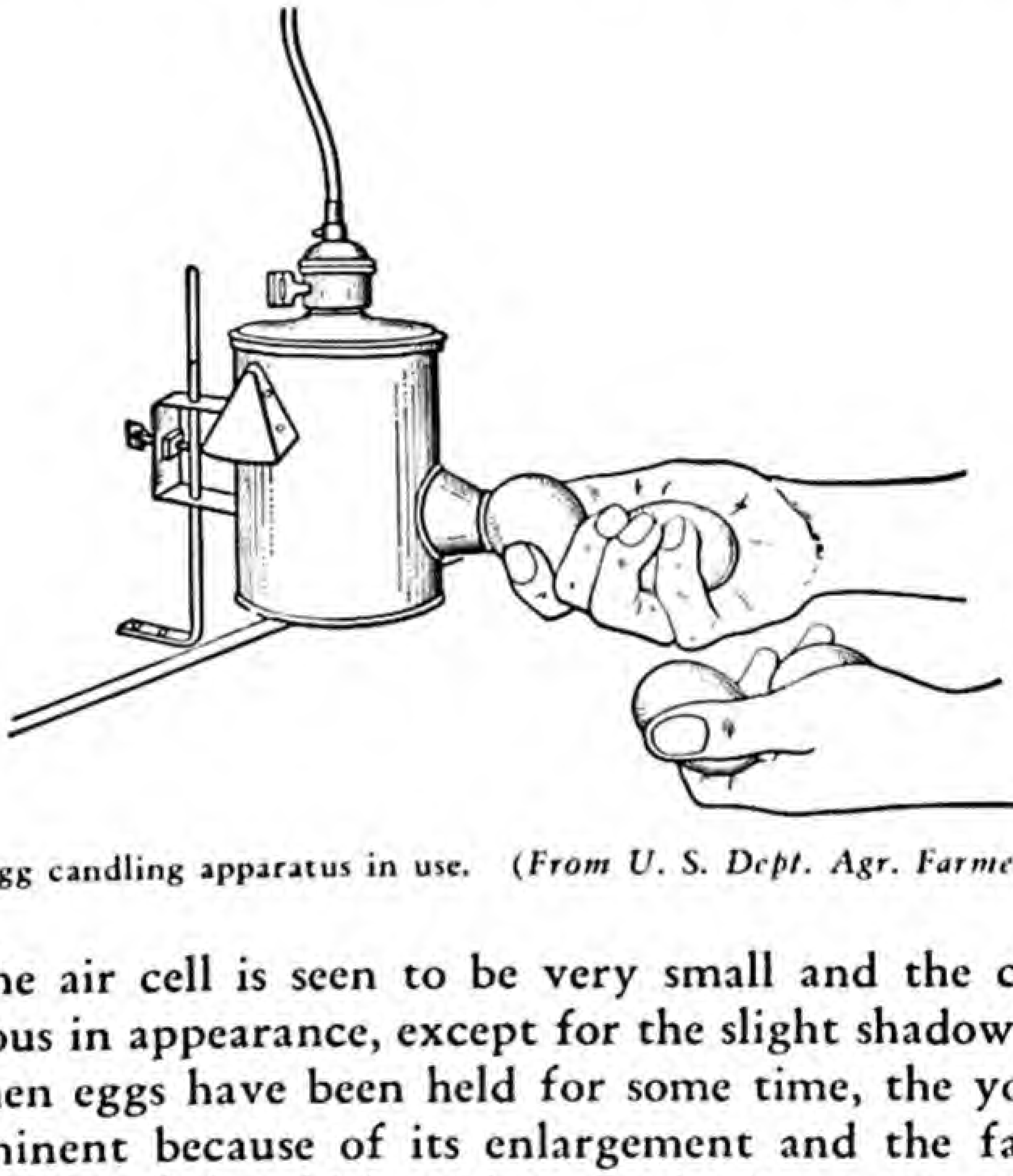


FIG. 19. An egg candling apparatus in use. (*From U. S. Dept. Agr. Farmers' Bull.* 1378.)

candled, the air cell is seen to be very small and the contents are homogeneous in appearance, except for the slight shadow cast by the yolk. When eggs have been held for some time, the yolk becomes more prominent because of its enlargement and the fact that increased fluidity of the thick white permits it to approach the shell more closely. Candling is considered a fair general measure of quality, but not a particularly accurate one.[14]

The U.S.D.A. has established four grades for shell eggs based on candling qualities. Grade AA eggs when broken out of the shell have clear thick whites and well-rounded yolks. Grade A have slightly less freshness as shown by a less spherical yolk and more fluid white. Differences between these two grades are insignificant. Eggs of these two grades are the best for poaching, frying, and cooking in the shell, and they separate most easily for whipping. Grade B

[14] Baker and Forsythe, *Poultry Sci.*, 30: 269 (1951).

eggs have somewhat flattened yolks and whites that spread more than those of Grade A quality. They are satisfactory for scrambling or for use in cooked mixtures. The whites show a little less stability when whipped and may be difficult to separate from the yolks without breaking the latter. Grade C eggs have flat yolks and thin whites and are suitable for cooking in food mixtures.

Grades as stated on labels apply, of course, to the date of labeling. Retailers should keep their eggs in a refrigerator to retard deterioration in the store. Many states have established grades which are similar to the federal grades and compulsory within their borders.

Economy of Eggs

Points to consider in relation to economy in buying eggs are (1) comparative costs of animal protein in other forms, (2) size, and (3) grade. The economy of eggs compared with other foods can best be judged on the basis of their contributions of animal protein. For animal protein equivalents see p. 298. As previously stated, eggs are usually more expensive than milk and similar in cost to lower-priced cuts of meat. Seasonal variations in price may be considerable and may justify larger consumption at some seasons than others. Of course, for certain cooking purposes eggs have no substitute.

In most markets, eggs are now classified in relation to size. Federal weight classes followed by many of the states are:

Jumbo	—at least 28 ounces per dozen.
Extra large	—at least 26 ounces per dozen.
Large	—at least 24 ounces per dozen.
Medium	—at least 21 ounces per dozen.
Small	—at least 18 ounces per dozen.
Peewee	—at least 15 ounces per dozen.

Although smaller eggs have a slightly larger proportion of shell than large, this is such a small item that one may compare values received on the basis of weight. Thus large eggs are worth one-seventh more than medium, medium one-sixth more than small, etc. Although many recipes are based on an amount of egg represented by "large" eggs, small variations are not important in most cases. Where the proportion of egg is important as in sponge or angel food cake, accurate recipes specify measure in terms of volume or weight rather than count.

When Grade B eggs are available the price is often at least 10 cents per dozen less than that for Grade A. They should be considered a better buy for uses for which they are suited, such as in baking.

In spite of the fact that some markets establish prices based on shell color, this has no relation to nutritional value or palatability of eggs.

FROZEN EGGS

Eggs that are marketed in the frozen state, like eggs that are dried, are to some extent those graded out because they are dirty, undersized, or cracked. They are then candled and, after being broken, individually inspected to eliminate all that are inedible. The frozen-egg industry has grown so rapidly, however, that it is now profitable to break high-grade eggs for freezing. Whites and yolks may be separated before being frozen or they may be churned together. The cans of the frozen product are sealed and held at a temperature of 15 degrees F. (-9 degrees C.) or lower until they are shipped.

The Appraisal of Frozen Eggs as Food

The nutritive quality and digestibility of eggs do not change with freezing.

Sanitary quality of frozen eggs depends upon that of the eggs at time of freezing, the effect of added substances, the amount of contamination from shells and workers when they are broken, and whether they are pasteurized or not. Freezing and frozen storage do not eliminate bacteria. Ten per cent of added salt causes more rapid reduction in bacterial count than the same per cent of sugar. Even when frozen eggs are used in cooked food mixtures, the temperatures employed for many that are high in egg content are so low that they do not ensure sterilization. Rigid sanitation should be practiced. Pasteurization of the liquid egg before freezing both destroys pathogenic organisms and prolongs keeping time of the products. It lowers very little or not at all the palatability of such products as angel and sponge cakes and custards made from it. Less of such egg yolk than unpasteurized yolks is needed in mayonnaise to give desirable stiffness, but there is no definite difference in flavor. Obviously eggs should be pasteurized as a safety measure before freezing.[15]

[15] Miller and Winter, *Poultry Sci.*, 29: 88 (1950).

Eggs which have been frozen decompose very rapidly when thawed and should be used within a few hours and never refrozen.

When egg yolks are frozen, their structure is so broken down that the thawed product is watery and ropy, a state caused by dehydration and coagulation of some of the yolk protein. Such egg yolk is unsuitable for combination with milk and oil in flour mixtures and salad dressings. It is common practice to add some substance, usually one of the sugars or salt, to protect against this coagulation. When this is done, frozen eggs are satisfactory substitutes for fresh or cold storage eggs in most food mixtures. In scrambled eggs, custards, or mayonnaise, frozen eggs are similar to fresh in palatability. If sugar is added to whole eggs or to the yolks if they are frozen separately, the frozen products are suitable for cake making.

Commercially frozen eggs are not yet sold for household use, but they are employed extensively by commercial bakers, ice cream and candy makers, and noodle and mayonnaise manufacturers. When frozen storage is available, eggs may be preserved by this method at home.

DRIED EGGS

Not only freezing but drying eggs has become such a profitable way of preserving them that high-grade materials as well as salvaged, undersized, dirty, and cracked specimens are treated in this way. After candling, the eggs are broken into individual cups and examined by sight and smell.

The three commonly used methods of drying eggs are the spray, belt, and tray methods. Whole egg and yolk may be spray-dried, but white alone is too viscous. Whites dry better by all methods if first liquefied by fermentation (enzyme action). For long holding, dried eggs should be refrigerated, but they will keep for some time at room temperature.

The Appraisal of Dried Eggs as Food

The principal change which takes place in the drying of eggs is the removal of about 90 per cent of the water. There is no important alteration in nutritive quality during drying and subsequent holding in refrigeration up to 9 months. They are frequently high in bacterial count, and *Salmonellae* occur in some samples.[16]

[16] Klose et al., *Ind. Eng. Chem.*, 35: 1203 (1943).

The most frequent source of contamination is dirty shells.[17] Dried eggs ought always to be used in cooked or pasteurized foods (not mayonnaise or eggnogs). Dried whole eggs are not well adapted to uses where their foaming properties are important, although it has been reported that sponge cakes of good quality can be made from them if the baking technic is modified somewhat.[18] The partially fermented dried whites will whip when reconstituted with water. Flour mixtures other than sponge cake, and custards made with dried whole eggs, are satisfactory in palatability, although different samples of the dried egg vary in cooking quality. In most flour mixtures, the egg powder may be sifted with dry ingredients but for custards, scrambled eggs, and omelets, it should be reconstituted first. To do this, equal measures of dried egg and water are stirred together, allowed to stand 5 minutes, and then beaten with a rotary beater until smooth. Approximately 2 tablespoons of dried egg (13.5 grams) plus an equal proportion of water equals one egg (48 grams). No more of the egg than can be used within the day should be reconstituted at a time, and it should be held in a refrigerator at all times.*

Dried eggs are used mostly by bakers, confectioners, ice cream makers, and manufacturers of flour mixes. When available at retail they are an economical substitute for fresh eggs. The biggest problem of the industry is to develop ways of prolonging the shelf life of the product to prevent the deterioration in flavor and color that have interfered with successful merchandising to date.

THE COOKING OF EGGS AND EGG MIXTURES

Cooking Eggs

The action of heat upon the proteins accounts for the principal changes occurring when eggs are cooked. Both white and yolk proteins are present as colloidal sols in the raw egg and coagulate when heated. The temperature at which coagulation begins, rate of coagulation, and firmness of the gel depend upon such factors as

[17] Solowey et al., *Food Res.*, 11: 380 (1946).

[18] LeClerc and Bailey, *Cereal Chem.*, 17: 279 (1940). Also Miller et al., *Food Res.*, 12: 332 (1947).

* For directions for using dried eggs in the household, see "Cooking with dried eggs," *U. S. Dept. Agr., Leaflet* AIS-28.

intensity of heat, length of the heating period, and the presence of added materials such as water, acid, sugar, and salt.

Eggs cooked in the shell at low temperatures, for example at 158 degrees F. (70 degrees C.), not only require a much longer time to coagulate than at higher temperatures, but the coagulated white is softer. After as long as 1 hour at this temperature the yolk shows increased viscosity, but not the structural rigidity of a gel. Undiluted whole egg begins to coagulate in the temperature range of 135 to 151 degrees F. (56 to 66 degrees C.) and gels at 158 to 165 degrees F. (70 to 74 degrees C.). The white by itself begins to coagulate at temperatures of 136 to 144 degrees F. (58 to 62 degrees C.) and gels at about 144 to 158 degrees F. (62.5 to 70 degrees C.).[19] Above about 176 degrees F. (80 degrees C.) egg white toughens.[20] (In all cases, the higher the cooking temperature, the more rapid is the coagulation and the firmer the gel.) It is obvious that the changes associated with the cooking of whole eggs and undiluted white or yolk can be produced at temperatures much below boiling by allowing more time for the heating. In fact, the products are rated as superior when lower temperatures are employed. (The exact time required for cooking eggs in the shell to a given degree of firmness depends upon the amount of water per egg, the temperature of the egg and water when cooking begins, and the rate of heating.)

The greenish-black discoloration on the surface of egg yolk, which sometimes appears when the egg is cooked in the shell, is a result of the formation of ferrous sulfide by union of iron in the yolk with hydrogen sulfide which is freed from sulfur compounds contained in the white. The amount of such discoloration depends upon the time and temperature of heating (30 minutes in water at 185 degrees F. [85 degrees C.] followed by rapid cooling in cold water gives little) and upon the age of the eggs (those 6 weeks old or more discolor more rapidly). (It is the hydrogen sulfide liberated during the cooking of eggs which tarnishes silver coming in contact with them.

For poaching and frying, new-laid or relatively fresh eggs are superior to those with larger proportions of thin white because this portion tends to spread and, in the case of poaching, to break off. Adding about 2 teaspoons of vinegar or lemon juice, or ¾ teaspoon of salt per pint of water used in poaching diminishes this difficulty.

[19] Payawal et al., *Food Res.*, 11: 246 (1946).

[20] Bass and Spencer, *Food Res.*, 14: 109 (1949).

Eggs in which thinning of the white has developed during holding are suitable for cooking in the shell, scrambling, or omelets.

Cooking Food Mixtures Containing Eggs

Important problems concerned with the culinary properties of eggs occur in connection with their use in food mixtures. They perform a variety of functions, the most important of which are outlined below.

Contributing to Flavor and Color, As in Many Flour Mixtures and Puddings

The yolk is most important in serving this function. Some factors affecting the color and flavor of the yolk have been mentioned.

Thickening, As in Custards and Cooked Salad Dressings

Dilution of the egg protein by adding milk or water raises the temperature at which coagulation takes place and tends to reduce the strength of the gel formed. If water rather than milk is added in the proportions used in making custard, coagulation results in a flocculent rather than a gel structure. Gel formation requires the presence of certain ions found in the milk.

When the egg is diluted and the mixture is heated, the viscosity increases and reaches a maximum with the formation of a gel if it is not stirred, and proportion of egg to other ingredients is appropriate. Further heating causes syneresis or curdling of the product. The rate of thickening and the temperature at which each stage occurs are affected by the concentration of egg, the intensity of the heat, and the presence of sugar, acids, or salts. In general, the faster the temperature of the mixture rises and the larger the proportion of sugar, the higher the temperature of coagulation. The higher the proportion of egg, of acid up to the isoelectric point, and of salt, the lower is the coagulation temperature.

When a cup of milk is added to an egg, the coagulation temperature is raised to about 176 degrees F. (80 degrees C.), higher if the rate of heating is rapid and lower if it is very slow. Gels similar in stiffness to those cooked to 178 degrees F. (70 degrees C.) can be obtained by heating a custard mixture to 158 degrees F. (70 degrees C.) and holding it there for 3 hours or more, showing that time and temperature of coagulation are dependent upon each other

in mixtures as well as in undiluted egg. In all custard mixtures, extended heating or excessive temperatures cause curdling or syneresis.

The addition of sugar produces a further elevation in the temperature necessary for gel formation, as much as 5 degrees F. (3 degrees C.) for a custard containing 4 tablespoons of sugar in 1 cup of milk. The temperature at which syneresis begins is likewise raised under these conditions. When the usual proportions of 1 tablespoon of sugar and 1 egg in 1 cup of milk are employed, and an ordinary rate of heating is used, the proper coagulation is reached between 176 to 183 degrees F. (80 to 84 degrees C.), and curdling develops at 185 to 189 degrees F. (85 to 87 degrees C.). The curdling temperature is somewhat lower when heating is very slow. Increasing the proportion of egg increases the firmness of the custard and produces thickening at a lower temperature. For this reason, 1½ eggs per cup of milk are recommended for custard pies. Substitution of 2 yolks for 1 whole egg raises the coagulation temperature, but the substitution of 2 whites lowers it. Equal amounts of white or yolk give a similar consistency to gels or other cooked mixtures.

Soft or stirred custards tend to curdle at lower temperatures than do baked custards. The maximum temperature to which soft custards should be heated is about 180 degrees F. (82.5 degrees C.) when the usual proportions of 1 egg, 1 cup of milk, and 1 tablespoon of sugar are used.

Since acid and salt promote coagulation of egg and egg mixtures, the larger the proportion of vinegar and salt in a cooked salad dressing, the thicker the product and the lower the temperature at which coagulation occurs. Maximum thickening of egg in such acid mixtures takes place between 169 degrees F. (76 degrees C.) and 185 degrees F. (85 degrees C.), and the cooking temperature should not exceed the latter. This means that the starch portion should be gelatinized before adding it to the egg because a higher temperature is required for complete gelatinization.

Contributing to Leavening by Foam Formation, As in Soufflés, Meringues, and Flour Mixtures

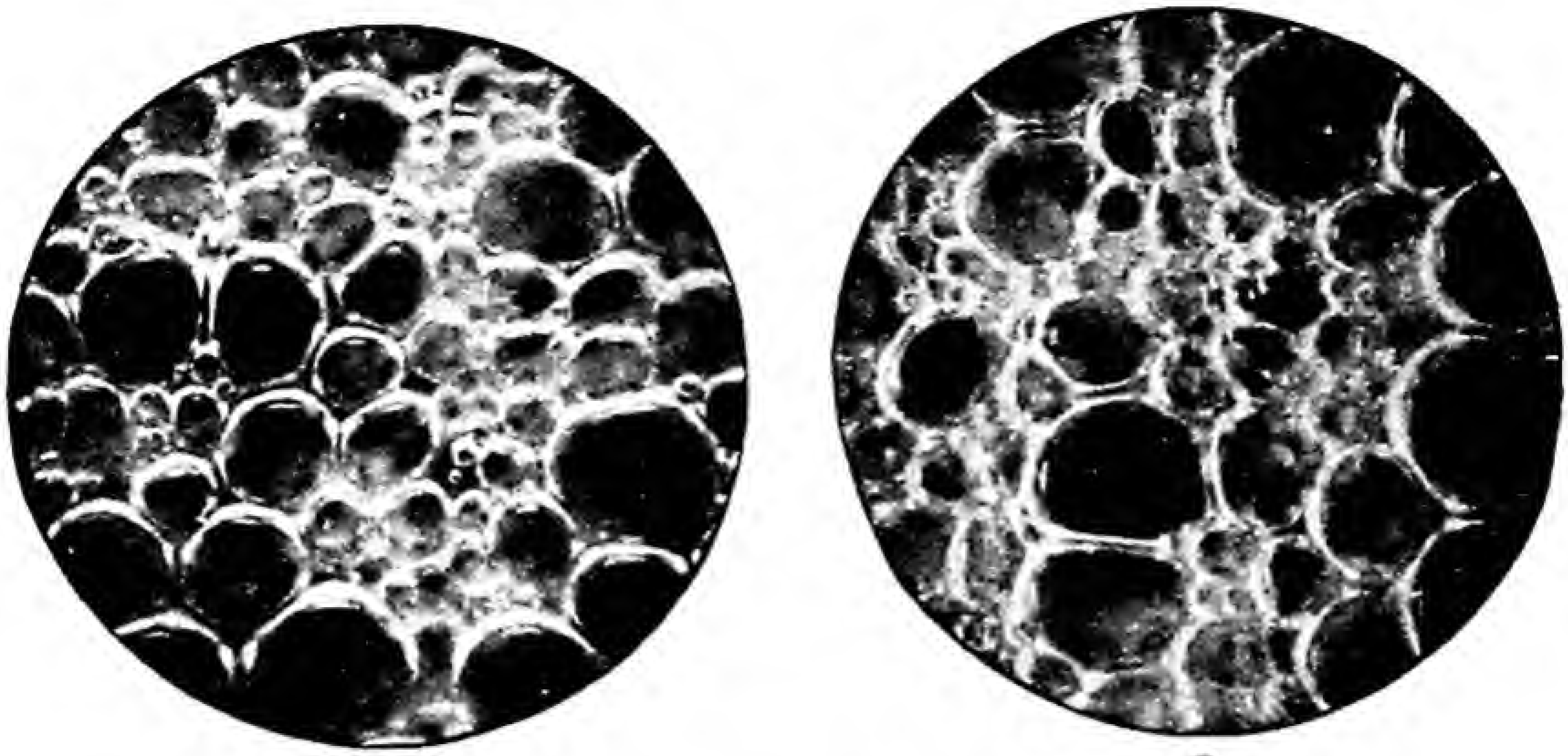
(See Chapter 15 for discussion of the latter.) A foam is a dispersion of the suspension type in which the dispersed phase consists of air bubbles. All liquids that contain substances capable of either positive or negative adsorption at the air-liquid interface will form foams because surface tension at the interface is thus lowered. If

the foam is to be stable, the material in the film must be viscous enough to resist thinning to the point where it ruptures. Egg white contains colloidal protein which fulfills this requirement. The longer whipping is continued, the more finely divided the air bubbles become and the more rigidity the foam structure develops. The protein micelles are packed so closely in the film that more or less coagulation occurs, and they become permanently modified in their properties. After the beating is discontinued, liquid begins to drain from the interfaces until the structure weakens at some point and the adjacent bubble or bubbles collapse. With this breakdown, more liquid is released for drainage.

The properties of egg-white foams which are of interest in food preparation include volume, stiffness, texture, and stability. For most uses, the volume and stiffness of the foam should be the maximum that is compatible with stability. The degree of stiffness which is regarded as optimum varies to some extent with the use of the foam. In general, the stiffer the whip, the more inelastic it becomes because of increased coagulation. The air bubbles in overcoagulated foams tend to coalesce on standing and thus collapse and "leak." (See Fig. 20.) Also, whenever the beaten white is to be cooked, it must not be whipped to a stage where the bubbles cannot swell as a result of expansion of the heated air that they contain, or the films will rupture and the product fall. On the other hand, if beating is insufficient, the foam structure will be coarse and uneven and lack the strength necessary to hold added ingredients, such as flour and sugar. Cookbooks commonly differentiate stages of stiffness according to the capacity of the foam to resist pouring or to maintain surface peaks. Uniformity in size of bubbles is desirable because it contributes to evenness in texture of the final product.

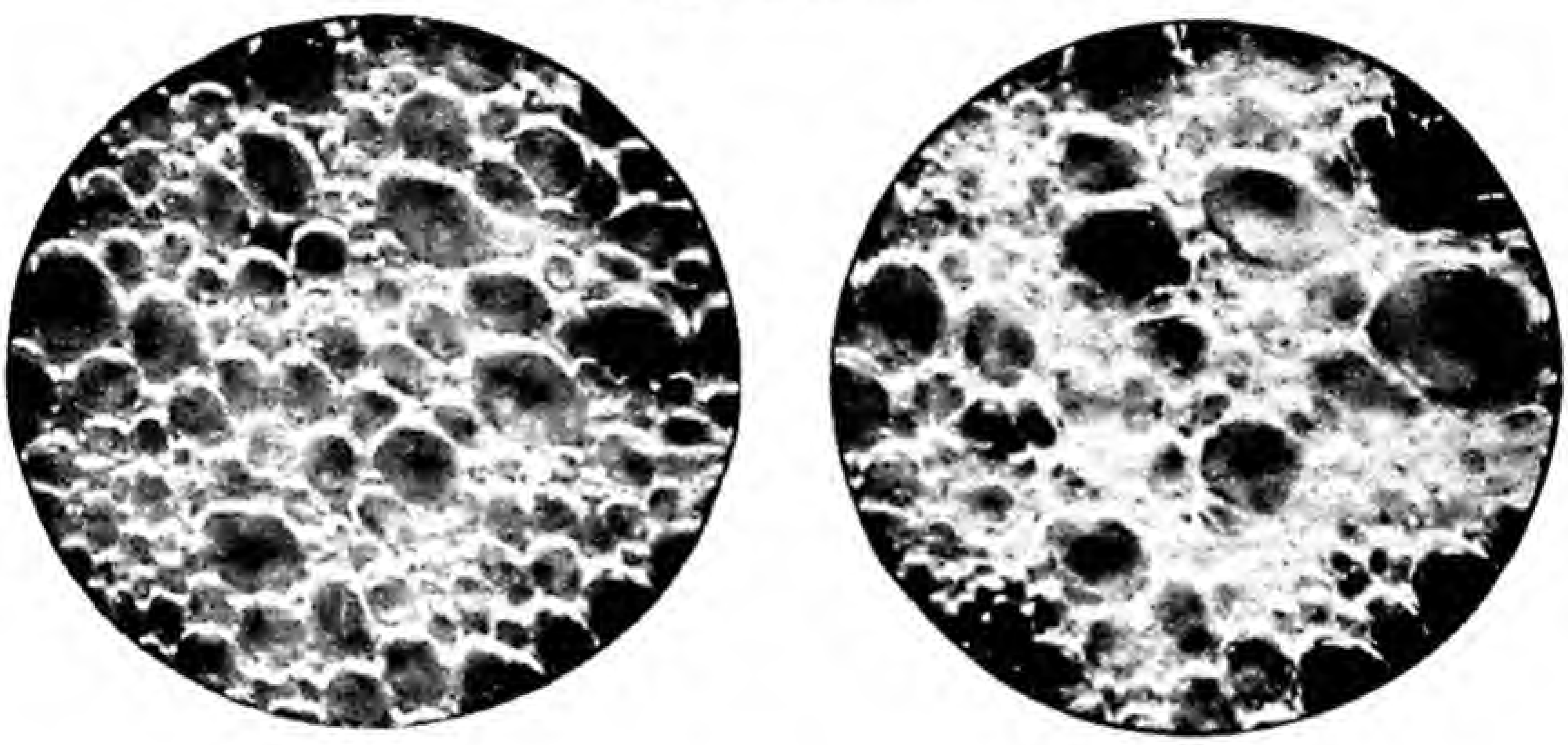
The properties of egg-white foams are affected by the individuality, age, and previous treatment of the egg, by its temperature when whipped, by the length of the whipping period, by the presence of added substances, and by the type of tool used for whipping. Such factors may affect several properties of the foam simultaneously, though not equally advantageously.

Natural variations cause no two egg whites to give exactly the same type of foam even under uniform treatment. There is general agreement that whipping proceeds more rapidly when eggs are warmed above refrigerator temperature, room temperature being much superior, and 86 degrees F. (30 degrees C.) better still so far as volume is concerned, but stability is lowered at the latter tem-



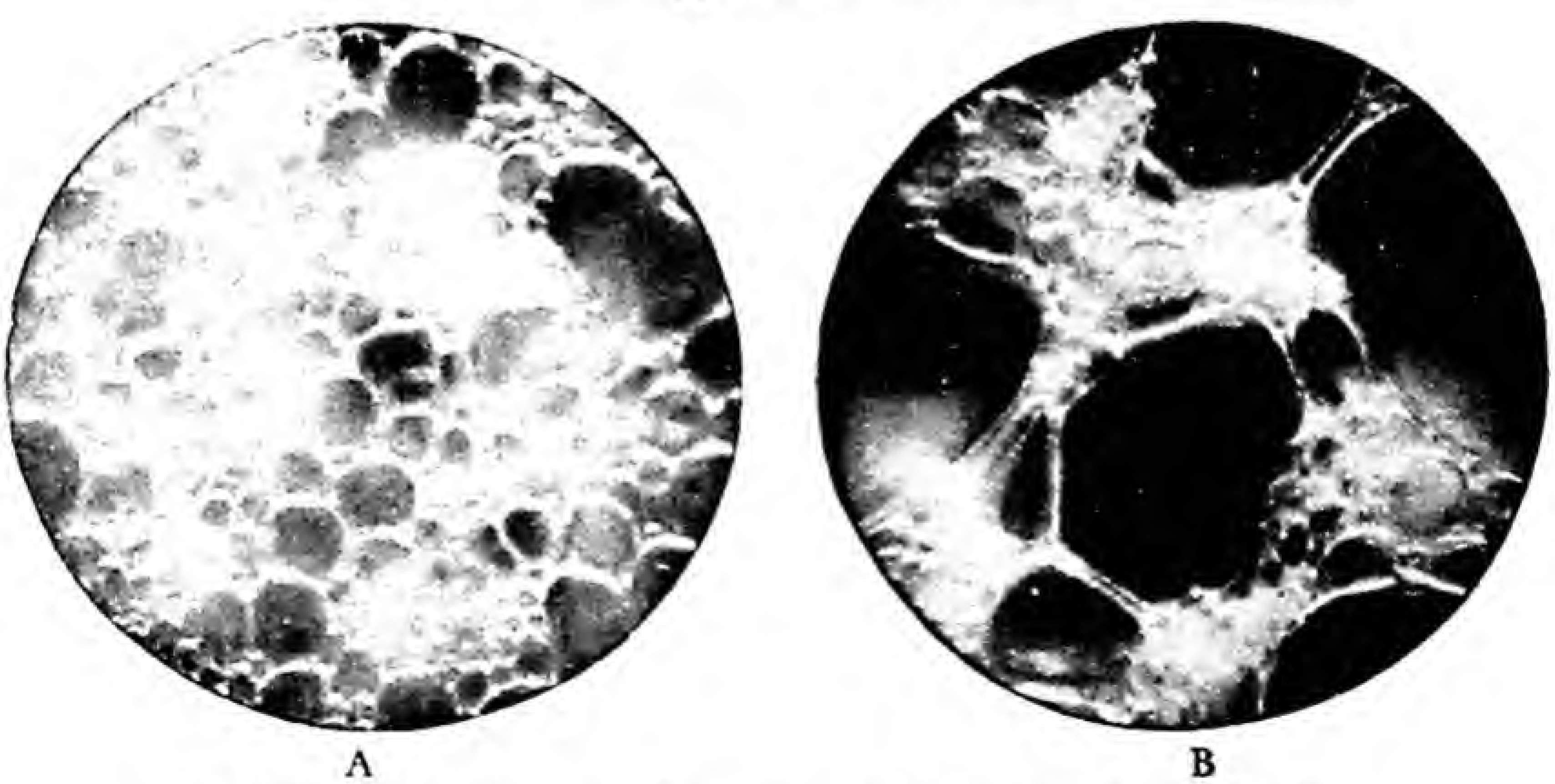
A B

Beaten 1 minute A. Appearance after standing 2 minutes
B. Appearance after standing 10 minutes



A B

Beaten 2 minutes A. Appearance after standing 2 minutes
B. Appearance after standing 10 minutes



A B

Beaten 5 minutes A. Appearance after standing 2 minutes
B. Appearance after standing 10 minutes

FIG. 20. Microphotographs showing the effect of beating for different periods on the texture and stability of egg-white foam. (*Courtesy M. A. Barmore.*)

perature.[21] At the optimum temperatures, surface tension is lowered and there is less resistance to the incorporation of air. Furthermore, the product has a finer, more even texture that gives correspondingly superior texture to such mixtures as angel food cakes. As measured by decreases in specific gravity, egg-white foams increase in volume at least up to 4 minutes of beating with a household power beater. The stability of the foam decreases, however, as the beating period lengthens,[22] and, to secure maximum stability, egg white should not be beaten to maximum volume.

Because the thinning of the whites that takes place during storage has often led to discrimination against storage eggs for culinary purposes that involve whipping, a number of studies have been made on the relative whipping qualities of thick and thin whites of fresh eggs and of the whites of stored eggs. When hand turbine or Dover egg beaters are used, thin whites and stored whites whip more quickly, the thin whites giving a larger volume and a texture preferable to that of the thick, and the storage whites giving at least as large a volume as the fresh. The foams from thin whites are less stable than those from thick, but thin whites and whole stored whites give angel food cakes of satisfactory volume. It has therefore been concluded that, when a power beater is not used under household conditions, discrimination against storage eggs for this use is not justifiable.

When power beaters are used, however, not only does the advantage of thin white (i.e., whipping more quickly than thick or whole white) disappear, but whole egg white and the separated thick portion give foams of superior volume and stability.[23] Workers in the BHNHE using a power beater found that whole whites and thick whites produced angel food cakes of tenderness and volume superior to those produced with thin white.[24] Probably the reason why fresh or thick whites were inferior to storage or thin whites in the former studies is that they are more difficult to beat with a hand beater.

In another study of the relatively poorer quality of cakes made from low-quality eggs, it was concluded: "The failure of eggs of inferior quality to yield high-quality cakes has been attributed to a considerable loss from the egg material of those factors which con-

[21] St. John and Flor, *Poultry Sci.*, 10: 71 (1931).

[22] Barmore, *Colo. Agr. Expt. Sta. Tech. Bull.* 9 (1934).

[23] Henry and Barbour, *Ind. Eng. Chem.*, 25: 1054 (1933).

[24] Anon., *U. S. Dept. Agr., Bureau of Home Economics Annual Rept.*, p. 5 (1934).

tribute structural strength to the cake during the baking process. One of these factors is the temperature of coagulation of the egg albumin. Investigations now in progress . . . show that this is raised considerably as eggs deteriorate. As the coagulation temperature is raised, it approaches closer and closer to the internal temperature attained by the cake in the baking process. The length of time the egg substance is held at a temperature equal to or above the coagulation temperature is thereby shortened. The resulting coagulum under these shortened heat treatments has considerably less strength."[25] This change is more noticeable at high altitudes where the boiling point of water is relatively lower than at sea level or low altitudes.

The effect of added substances on the properties of egg-white foams has been the subject of much study. The depressing effect of very small amounts of yolk on volume and speed of whipping has been commonly noted and has been attributed to the fat content of the yolk. Amounts of a more concentrated fat such as olive oil equivalent to the egg yolk fat have a still more deterrent effect on whipping. Milk and cream also interfere, but very much larger quantities of separated (skim) milk are required to give this effect.[26] The fact that homogenized milk and cream produce much less interference than do the corresponding unprocessed materials makes it probable that the small size of the fat particles in these products and in egg yolk is responsible for their diminished effect as compared with the unprocessed milk and cream in the one case and with the olive oil in the other.

Because many foods containing whipped egg also contain acid ingredients, the effect of added acids on the volume and stability of egg-white foams has been studied. Normal egg white is alkaline (about *p*H 7.9 for fresh and *p*H 8.9 for storage whites), and there is general agreement that increasing its acidity to *p*H 4.8 markedly increases its stability. Acetic, citric, cream of tartar, and other acids produce the same general effect, with cream of tartar giving the most stable foam. This permits it to expand more with heat and to hold up better during the addition of other ingredients.

According to common household practice, water may be added to egg whites before they are whipped. One study in which a power beater was used led to the conclusion that increase in volume and

[25] Pyke and Johnson, *Poultry Sci.*, 20: 125 (1941).

[26] Dismay and Sunderlin, *J. Home Econ.*, 25: 729 (1933).

stability of egg white and water mixtures containing up to 40 per cent by volume of added water makes them equivalent to the same amount of undiluted egg whites. Further increase of water up to 80 per cent volume produces increase in foam volume, but the foams are unstable as indicated by loss of liquid on standing and by their tendency to break down when they are beaten. The BHNHE reports that dilution of whole and thick whites with water increases the softness of angel food cake, but, although adding not over 10 per cent water gives satisfactory products, the best angel food cakes are made from undiluted whites.* Probably the relative desirability of dilution varies with the use made of the foam and perhaps also with the type of beater used.

Adding sugar to egg whites increases the stability of the foam formed, but more time and energy are required for whipping and it may be impossible to get desired volume. Adding the sugar after considerable volume is obtained gives the advantages of increased stability without interfering with volume. One method of mixing sponge-type cakes is to whip part of the sugar with the egg white because the increased stability results in less loss of air at the time when other ingredients are incorporated. Measures which conserve air in foams in which other ingredients are to be incorporated include combining promptly after the foam is formed and the use of gentle folding motions which do not break the air bubbles.

The type of beater has been studied in relation to the properties of egg-white foams it produces. In discussing hand tools, both beaters and wire whips, Lowe concluded that, with any type, the size of bubbles decreases as whipping is prolonged and the texture becomes more uniform. Although fine wire whips tend to give more large bubbles at first than do the rotary beaters, and in the hands of most people give a larger volume at the end, it is possible to manipulate both to give final products of very similar texture. It has been mentioned previously that hand beaters may be less effective than power types in producing a large volume of foam, especially in the thicker whites. In this connection, it is perhaps well to remember that the final volume of the product containing the foam may depend more upon the stability of the foam than upon its original volume.

Food mixtures containing large proportions of egg-white foam must be baked for carefully limited periods of time or they will be tough. The temperature should be such that a proper degree of ex-

* See reference 24.

pansion develops before the outer layer is coagulated. Usually this requires a relatively low temperature. In baking egg mixtures, such as custards and soufflés, standing the container in water results in slower heating and more even cooking. Egg foams, like whole eggs, are more tender when they are coagulated at low temperatures than when greater heat is used, but this does not mean that high cooking temperatures always give less tender products. The time and temperature required for doneness are affected by other ingredients.

The Appraisal of Cooked Eggs

Cooking eggs results in small losses (up to about one-sixth of the original) of thiamine and riboflavin, the amount varying with the method.[27] Although cooking in strong daylight slightly increases losses of riboflavin, this vitamin is much more resistant to such inactivation in eggs than in milk

Cooked whole-egg protein is 96 per cent absorbed.[28] The method of cooking does not influence the completeness of digestion of eggs, but it may alter the length of time that they are held in the stomach. Soft-cooked eggs leave the stomach a little more rapidly than hard-cooked, perhaps because the latter are less completely disintegrated when they are masticated. Contrary to popular belief, eggs fried with a moderate amount of fat leave the stomach as quickly as those cooked by other methods.

Although the temperatures reached in ordinary cooking of eggs usually result in the killing of pathogenic organisms, this is not always true in soft-cooked whole eggs. Washing the shells before breaking is a worth-while precaution. Food poisoning is the principal hazard, and in most cases it follows contamination after cooking with several hours of subsequent warm storage. All cooked products containing large amounts of egg, such as custards or custard fillings, should always be held in a refrigerator and for a limited time only.

In general, the palatability of cooked eggs and of food mixtures containing large proportions of egg depends chiefly upon the time and temperature of cooking, provided, of course, that the raw product is of suitable quality.

[27] Stamberg and Petersen, *J. Am. Dietet. Assoc.*, 22: 315 (1946). Also Hanning et al., *Food Res.*, 14: 203 (1949).

[28] Murlin et al., *J. Biol. Chem.*, 156: 785 (1941).

SUMMARY OF POINTS TO CONSIDER IN SELECTING AND USING EGGS

1. Buying eggs to be eaten as eggs should be limited until the budget covers recommended amounts of milk, because milk contains the more important nutrients of eggs at lower cost with indispensable calcium in addition.

2. Eggs should be stored in a closed container in a refrigerator at all times. Cooked egg mixtures should also be refrigerated if held.

3. As a sanitary precaution, the shells of eggs should be washed just before they are broken for use.

4. When Grade B eggs are available, they are usually a good buy for preparation by scrambling or in food mixtures.

5. When available, sizes other than medium or large are often priced to make them relatively economical.

6. Some type of household storage of eggs from spring to late fall may save money.

7. Following recommended procedures for whipping and cooking eggs gives products of highest palatability. Overheating and overbeating should be avoided.

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CHAPTER 12

MEAT AND ALLIED FOODS

The structure and composition of meat.
The appraisal of meat in unprocessed forms.
The cooking of meat.
 The general effects of heat on meat.
 The methods of cooking meat.
 The appraisal of cooked meat.
Frozen meats and their appraisal.
Cured meats and their appraisal.
Smoked meats and their appraisal.
Dried meats and their appraisal.
Canned meats and their appraisal.
Gelatin.
 The structure and composition of gelatin.
 Gelatin in food preparation.
 The appraisal of gelatin as a food.
Summary of points to consider in selecting and preparing meats.

Traditionally, a distinction is made between meat and poultry, and between both of these and sea foods, but this distinction is justified neither by variations in composition and nutritive quality nor by differences in principles of preparation. Most of the important generalizations about the preparation of meat and its equivalent as food apply to all flesh foods.

The animals of which the flesh is commonly used for food include the mammals: cattle, sheep, hogs, and rabbits; the birds: chickens, ducks, geese, turkeys, and guinea fowls; the crustaceans: crabs and lobsters; the molluscs: oysters, clams, and snails; the amphibians: frogs; the reptiles: turtles; and the fishes. The bulk of such foods consumed in this country is derived from the domestic mammals and birds and fishes. The annual per capita consumption of these by decades since 1918 is given in Table XXXVII. Declining consumption of meat and allied foods during the decades of the twenties and thirties was succeeded by a rapid rise in the forties. This was doubtless a result of increased purchasing power. Except for fruits and

Table XXXVII. Approximate per capita consumption of meat and allied foods, 1918–1948

[From *U. S. Dept. Agr., Misc. Pub.* 691 (1949)]

	Pounds per capita			
Kind of flesh food	1918	1928	1938	1948
Beef	53.7	38.2	42.7	50.1
Veal	6.6	5.8	6.9	8.6
Lamb and mutton	4.2	4.9	6.1	4.4
Lean pork	39.4	45.8	37.6	44.7
Edible offal	10.5	9.0	8.4	10.3
Game	2.6	1.8	1.6	2.0
Chicken and turkey	19.0	21.7	19.5	26.7
Fish and shellfish	11.2	12.5	11.1	11.0
Total	147.2	139.7	133.9	157.8

vegetables, consumption of flesh foods increases more at higher income levels than that of any other major class of food.[1]

THE STRUCTURE AND COMPOSITION OF MEAT

Meat is composed for the most part of muscle tissue, connective tissue, and fat. Muscle tissue is made up of bundles of muscle fibers called *fasciculi.* Each bundle possesses an envelope of connective tissue, the *perimysium,* which continues on into the tendon at the end of the bundle and anchors the muscle to the bone. Blood vessels, nerves, and fat cells are also imbedded in the masses of connective tissue lying between the bundles of fibers. (See Fig. 21.) Each individual muscle is enclosed in a sheath of connective tissue known as the *epimysium.*

The individual muscle fibers are spindle-shaped cells varying in diameter from $\frac{1}{200}$ to $\frac{1}{1100}$ inch and sometimes becoming 1 to 2 inches long. Each fiber is encased in a membranous sheath, called the *sarcolemma.* The fiber consists of a contracting substance, which appears to be in the form of minute rods called *fibrillae,* and a solution of other muscle-tissue constituents, including the extractives and minerals, called *sarcoplasm.* The proteins of the fiber consist chiefly of myosin and myogen, together with small amounts of muscle albumin and globulin, and myoglobin, the muscle pigment.

[1] "Consumption of food in the United States," *U. S. Dept. Agr., Misc. Pub.* 691 (1949).

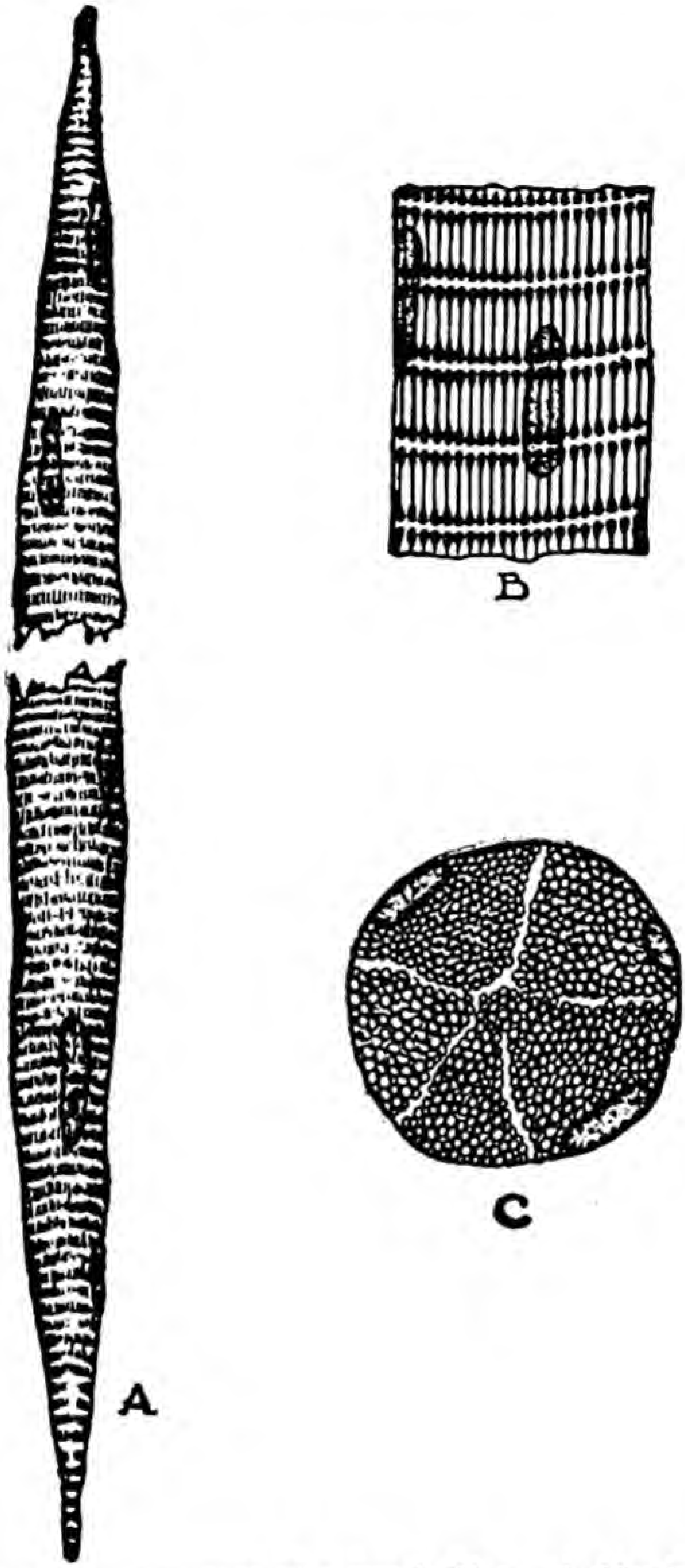


FIG. 21. The microscopic appearance of a muscle fiber. *A.* Muscle fiber, cylindrical in shape, 1/500 inch in diameter, and often an inch or more in length. *B.* Longitudinal section, very highly magnified. *C.* Cross section, very highly magnified. (*Courtesy of Robert Moulton and permission of University of Chicago Press.*)

Connective tissue is composed largely of two proteins, elastin and collagen. There are two types of connective tissue, the white and the yellow. Yellow connective tissue contains a large proportion of elastin; the white contains mostly collagen. The function of connective tissue is to bind together the bundles of muscle fibers within the individual muscle and to attach muscles to other muscles or bones. Tendons and ligaments are composed largely of connective tissue, the tendons containing mostly the white type and the ligaments more of the yellow type. Connective tissue in the muscles is responsible for toughness in meat. Like the muscle fiber, connective tissue is colloidal in its minute structure.

Some fat is present in all meat. It is deposited in the connective tissue around organs, around and between muscles, and under the skin. The fat which is laid down in the connective tissue between the fasciculi is especially prized because it improves the flavor and juiciness of the meat. The extra juice consists of the melted fat and the water which is present in fatty tissue. Meat containing visible fat distributed in this way is called marbled. See Table XXXVIII for the composition of typical meats and other flesh foods.

Table XXXVIII. The proximate composition of meat and other flesh foods *

(A.P., As Purchased; E.P., Edible Portion)

Flesh food	Percentage composition					
	Water	Protein	Fat	Carbohydrate	Ash	Refuse
Beef, round, medium fat, E.P.	67.0	19.3	13.0	...	0.95	....
Veal, leg cutlets, E.P.	70.7	20.3	7.7	...	1.1	....
Lamb, hind leg, medium fat, E.P.	63.7	18.0	17.5	...	0.9	....
Pork, ham, medium fat, E.P.	53.9	15.3	28.9	...	0.8	....
Chicken, fowl, E.P.	55.9	18.0	25.0	...	1.1	....
Goose, E.P.	51.1	16.4	31.5	...	0.9	....
Turkey, E.P.	55.5	21.1	22.9	...	1.0	....
Beef organs:						
Kidney, A.P.	74.9	15.0	8.1	0.9	1.08	....
Liver, E.P.	69.7	19.7	3.2	6.0	1.4	....
Sweetbreads, E.P.	54.0	11.8	33.0	...	1.11	....
Tongue, E.P.	68.0	16.4	15.0	0.4	0.86	26.5
Cod, E.P.	82.6	16.5	0.4	...	1.2	....
Halibut steak, E.P.	75.4	18.6	5.2	...	1.0	....
Salmon, E.P.	64.6	22.0	12.8	...	1.4	....
Clams, round, E.P.	79.8	11.1	0.9	5.9	2.3	....
Oysters, E.P.	80.3	9.8	2.0	5.9	2.0	....
Scallops, E.P.	80.3	14.8	0.1	3.4	1.4	....
Crabs, E.P.	80.0	16.1	1.6	0.6	1.7	....
Lobster, E.P.	79.2	16.2	11.9	0.5	2.2	....

* *U. S Dept. Agr., Circ.* 549 (1940).

THE APPRAISAL OF MEAT IN UNPROCESSED FORMS

With the exception of shellfish, practically no uncooked flesh is eaten by civilized man. Occasionally, certain foreign sausages are consumed after being cured and smoked only, but, in the United States at least, some degree of cooking is almost always employed for this class of foods. Although all the qualities by which we evaluate these foods as we eat them (nutritive quality, palatability, etc.) are affected by the cooking and subject to some control during this process, such changes are limited by the composition and structure of the particular piece of flesh before cooking. Just what these relationships are is only incompletely understood. Even when they are known, it may be difficult to explain how the consumer-buyer can identify the significant factors at the market.

In general, the principal factors controlling composition and structure and through them the general evaluation of freshly killed flesh foods are species, section of the body (cut), age, sex, past environment (especially feed), exercise, and heredity. Of these, species and cut can readily be ascertained at the market. To a limited extent, the others may be reflected in appearance, especially in such qualities as the relative proportions of bone, fat, and muscle, and the color and texture of each. These qualities are the basis of grading meats, as will be discussed later. Common types of processing which may precede cooking and which also affect the appraisal of these foods include ripening, freezing, curing, smoking, and drying.

Variations of composition and structure within the carcass of the common meat animals are relatively great. The flesh of different regions of the body possesses different qualities which are a natural result of the adaptation of structure to function. The market recognizes structural variation in all the larger food animals by selling their flesh in standardized or carcass divisions. Although the system of cutting may vary somewhat with the locality, all methods aim to attain uniformity within the cut, and to apportion a maximum proportion of the carcass to the cuts in greatest demand. So far as possible, divisions are made at joints or between bones, and muscles are cut across the grain. See Figs. 22, 23, 24, 25, 26, 27, 28, 29 for the cuts of beef, pork, veal, and lamb according to the Chicago style, which is recommended for country-wide adoption.

Three other methods of cutting beef are employed to a limited extent. These include the Philadelphia, New York, and Boston styles. (See Fig. 30.)

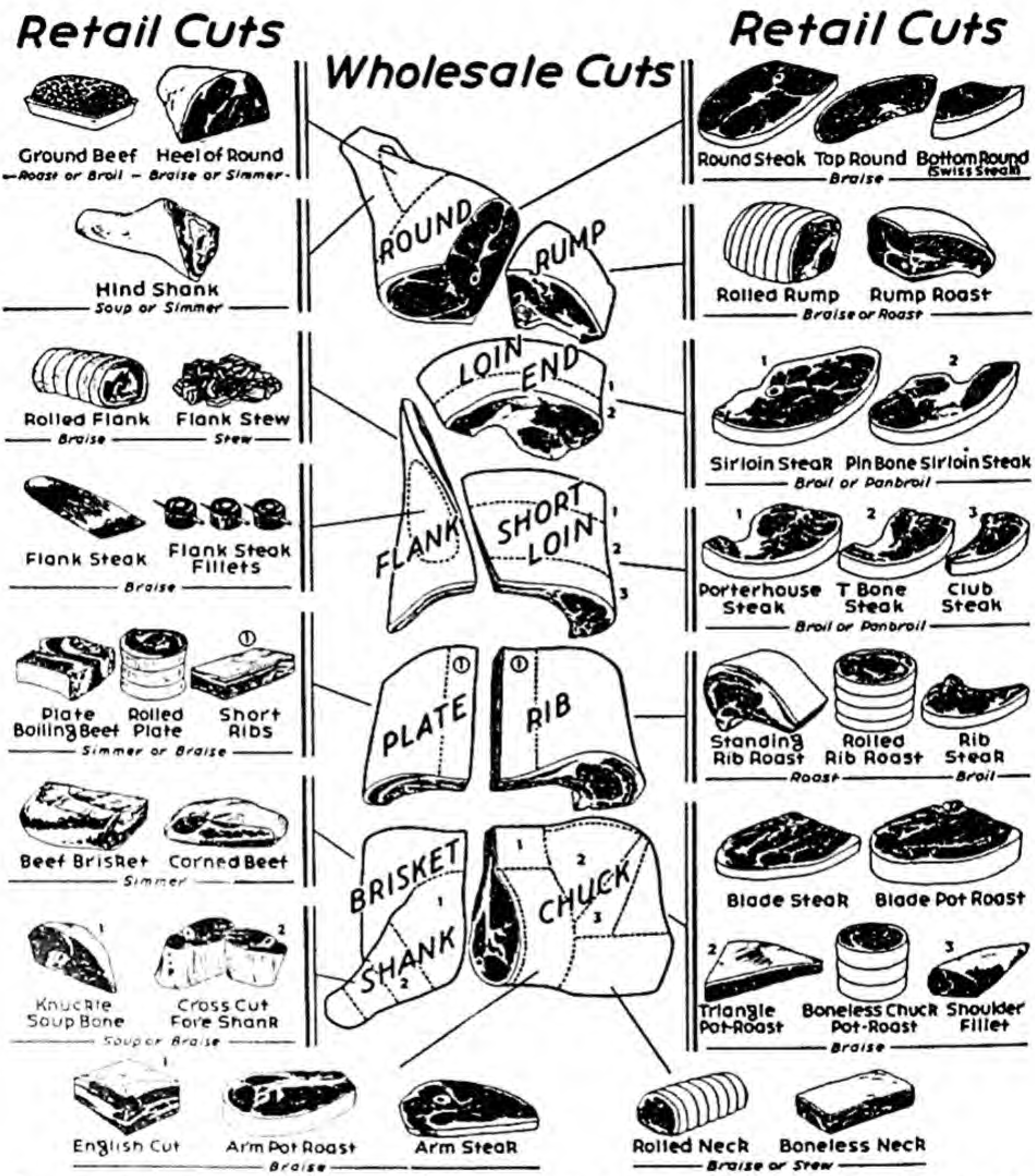


FIG. 22. Beef, wholesale and retail cuts. (*Courtesy National Live Stock and Meat Board.*)

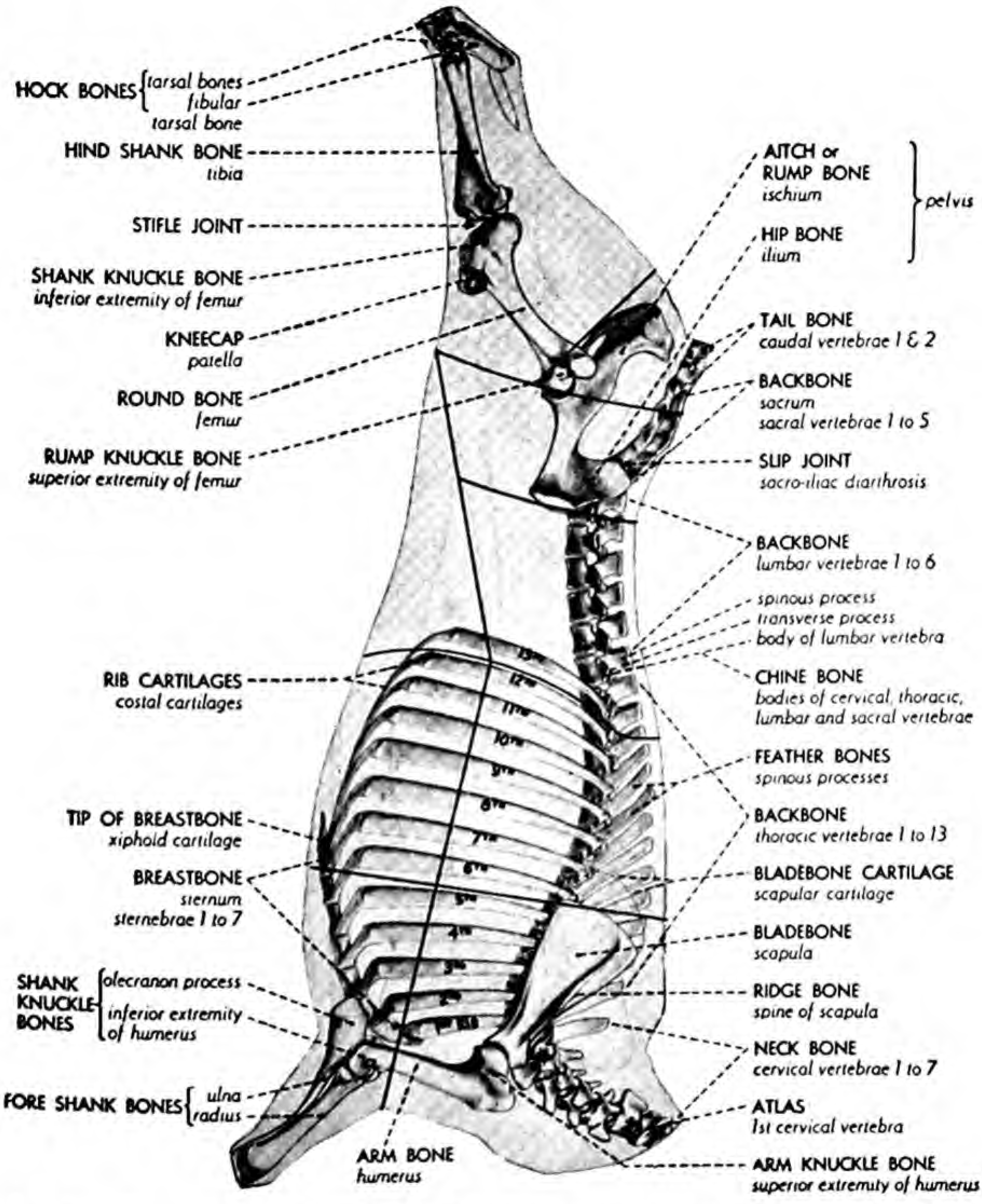


FIG. 23. The relation of beef cuts to skeletal structure. (*Courtesy National Live Stock and Meat Board.*)

FIG. 24. Veal, wholesale and retail cuts. *(Courtesy National Live Stock and Meat Board.)*

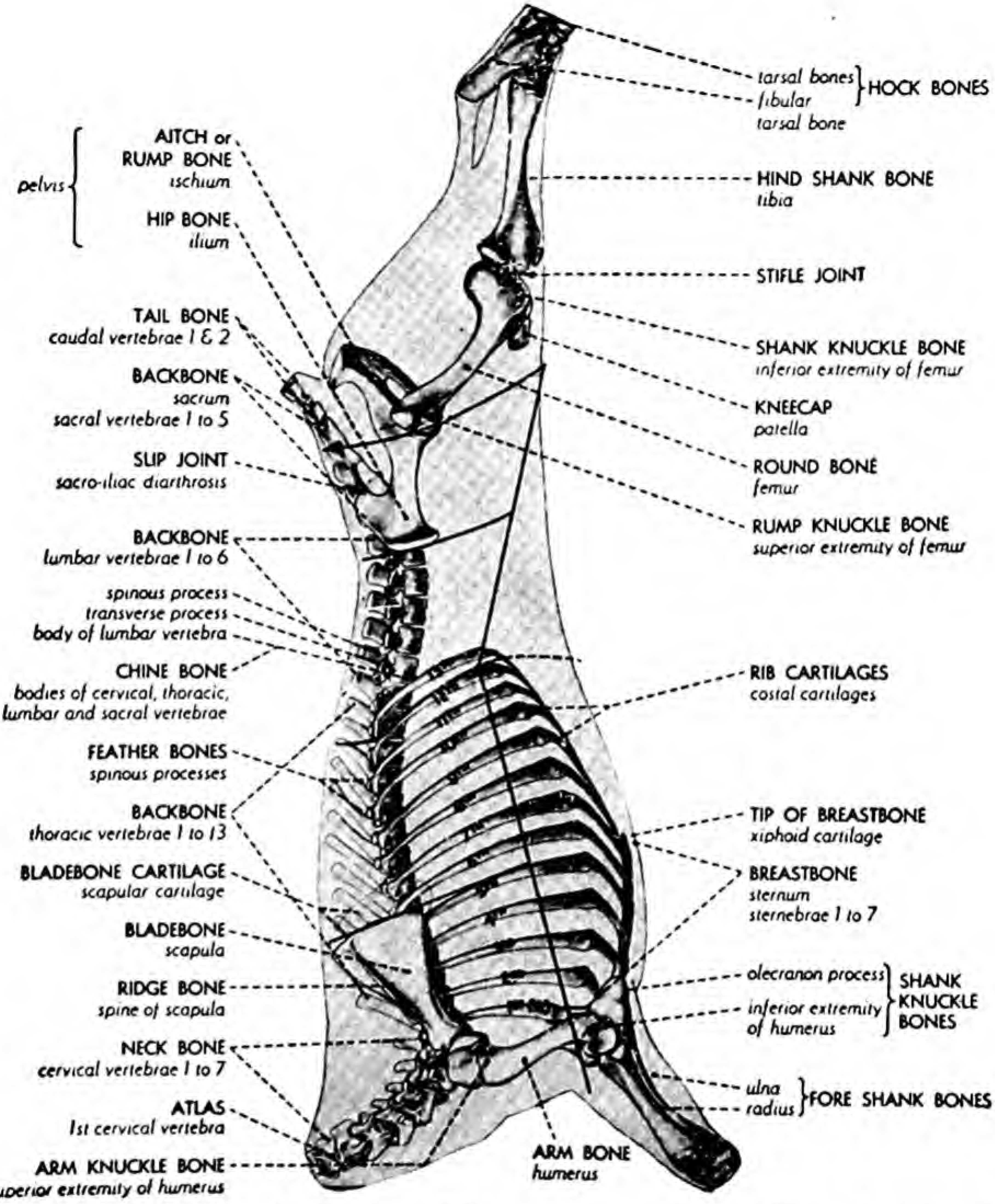


FIG. 25. The relation of veal cuts to skeletal structure. (*Courtesy National Live Stock and Meat Board.*)

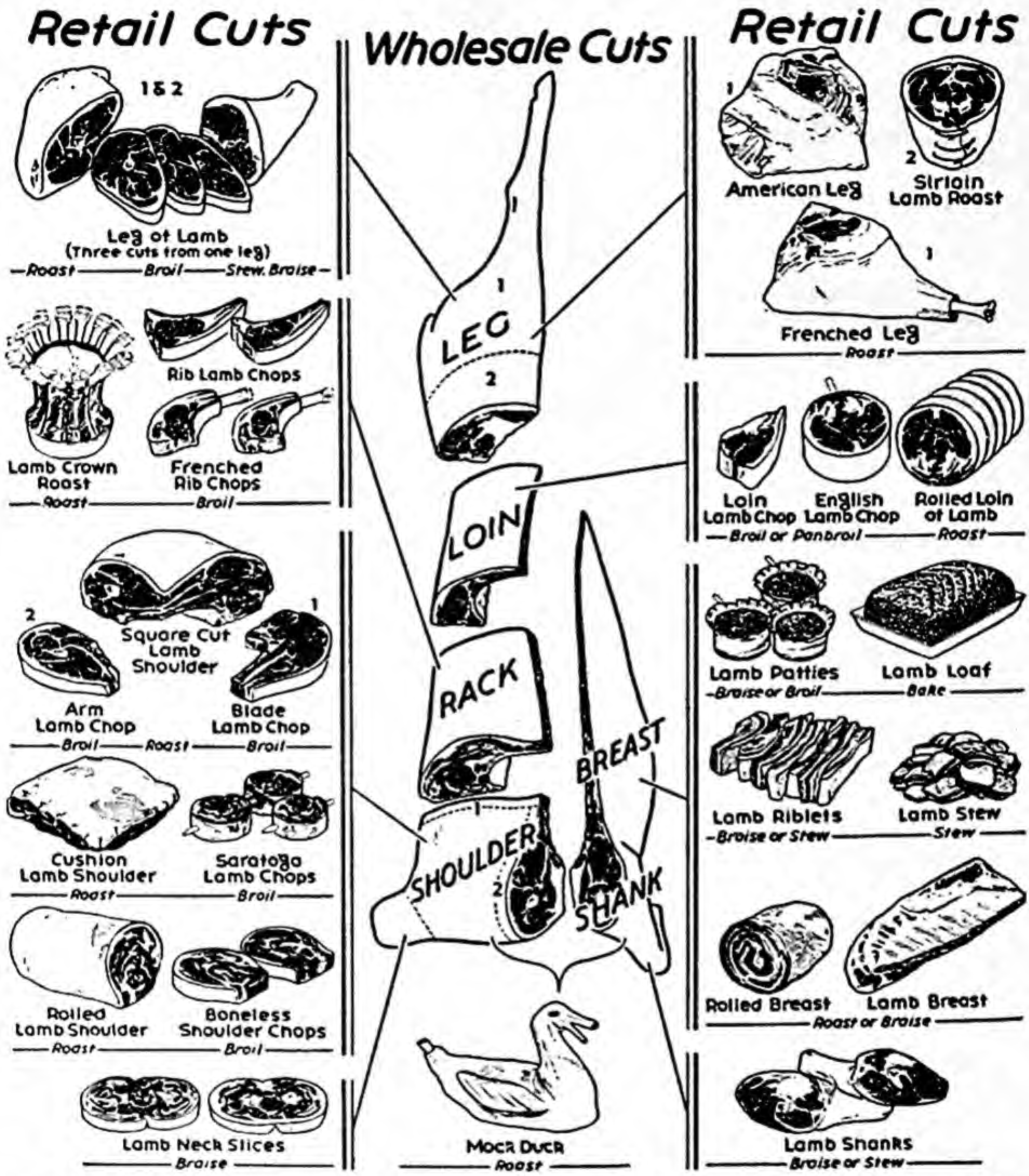


FIG. 26. Lamb, wholesale and retail cuts. (*Courtesy National Live Stock and Meat Board.*)

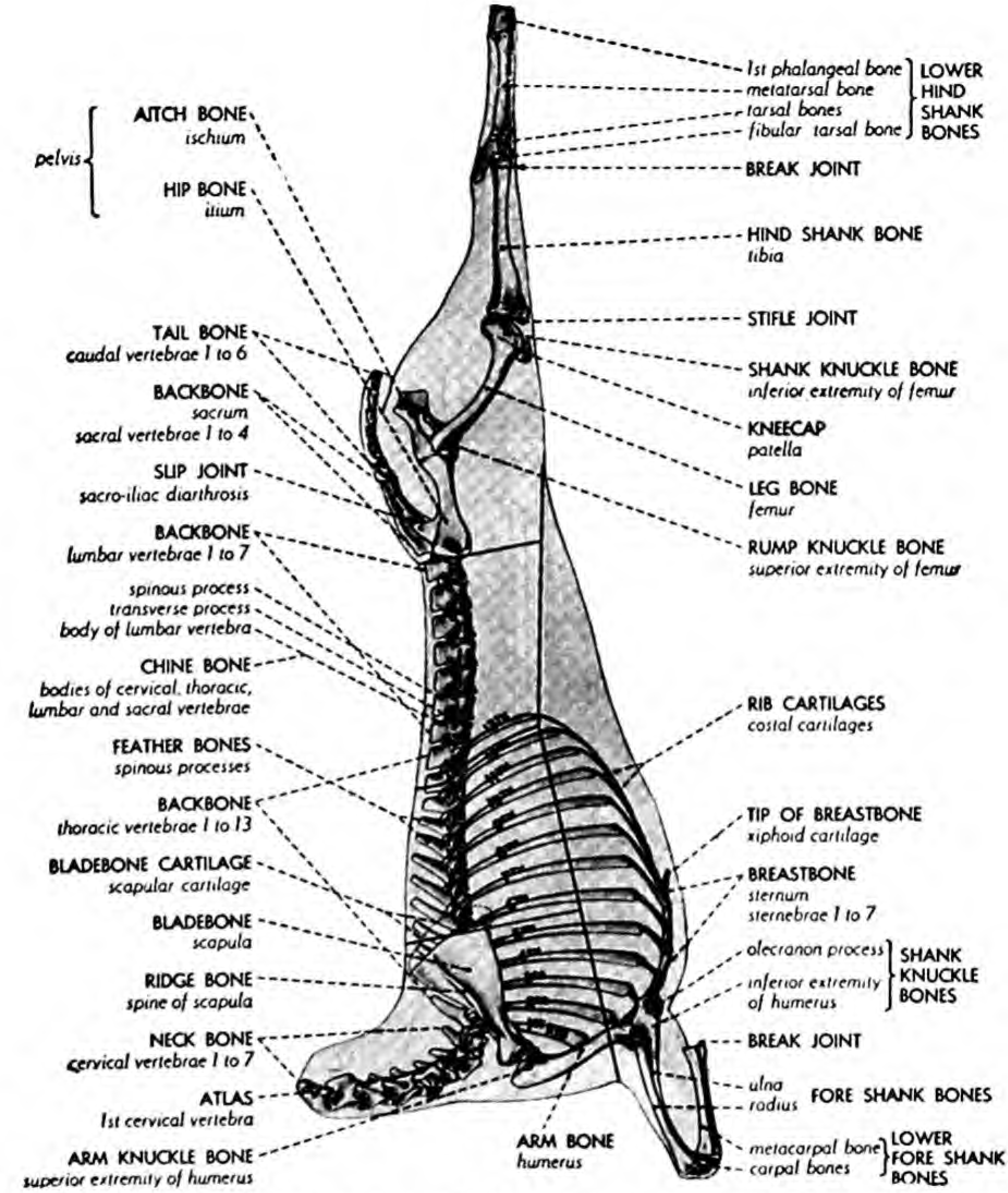


FIG. 27. The relation of lamb cuts to skeletal structure. (*Courtesy National Live Stock and Meat Board.*)

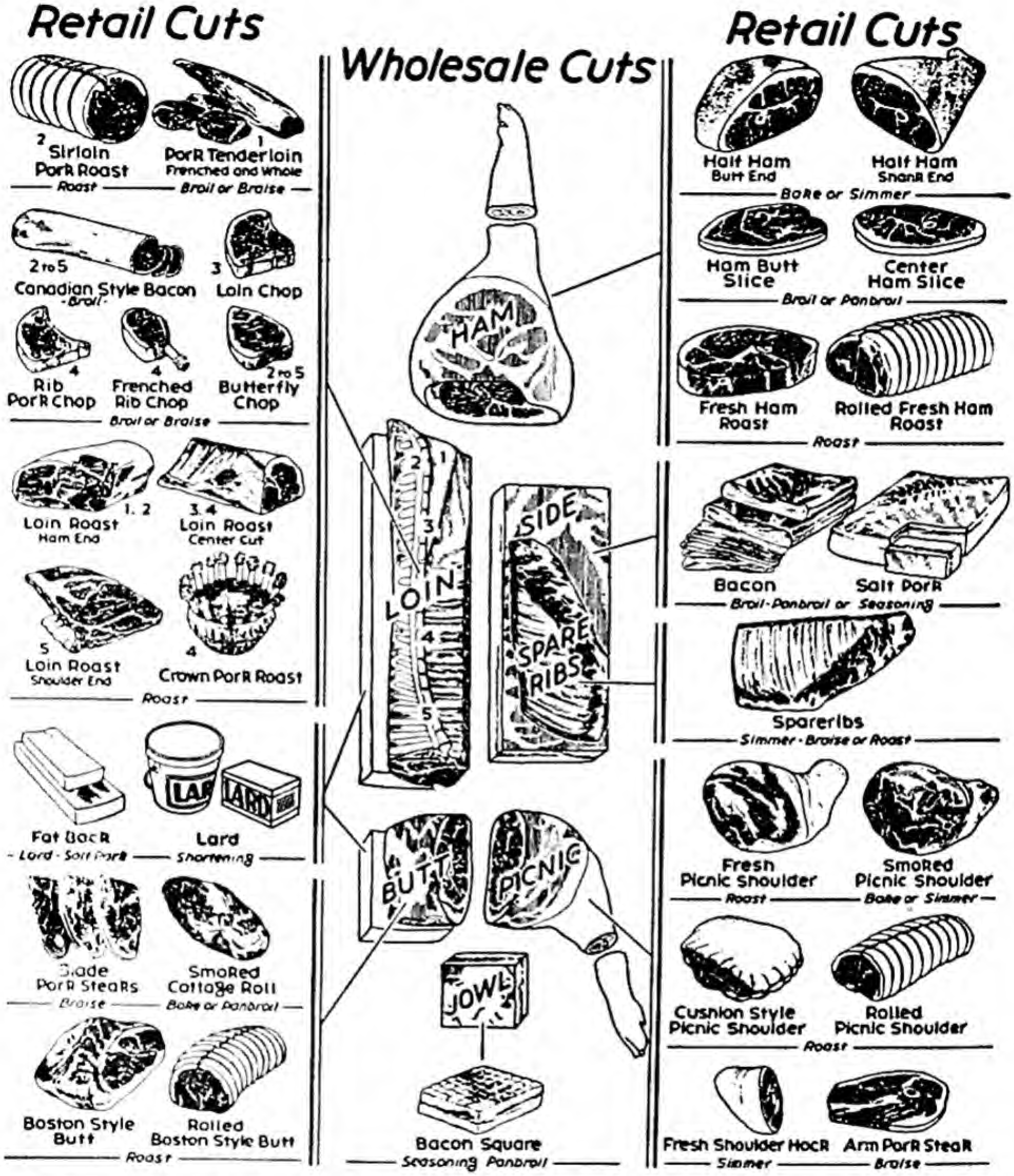


FIG. 28. Pork, wholesale and retail cuts. (*Courtesy National Live Stock and Meat Board.*)

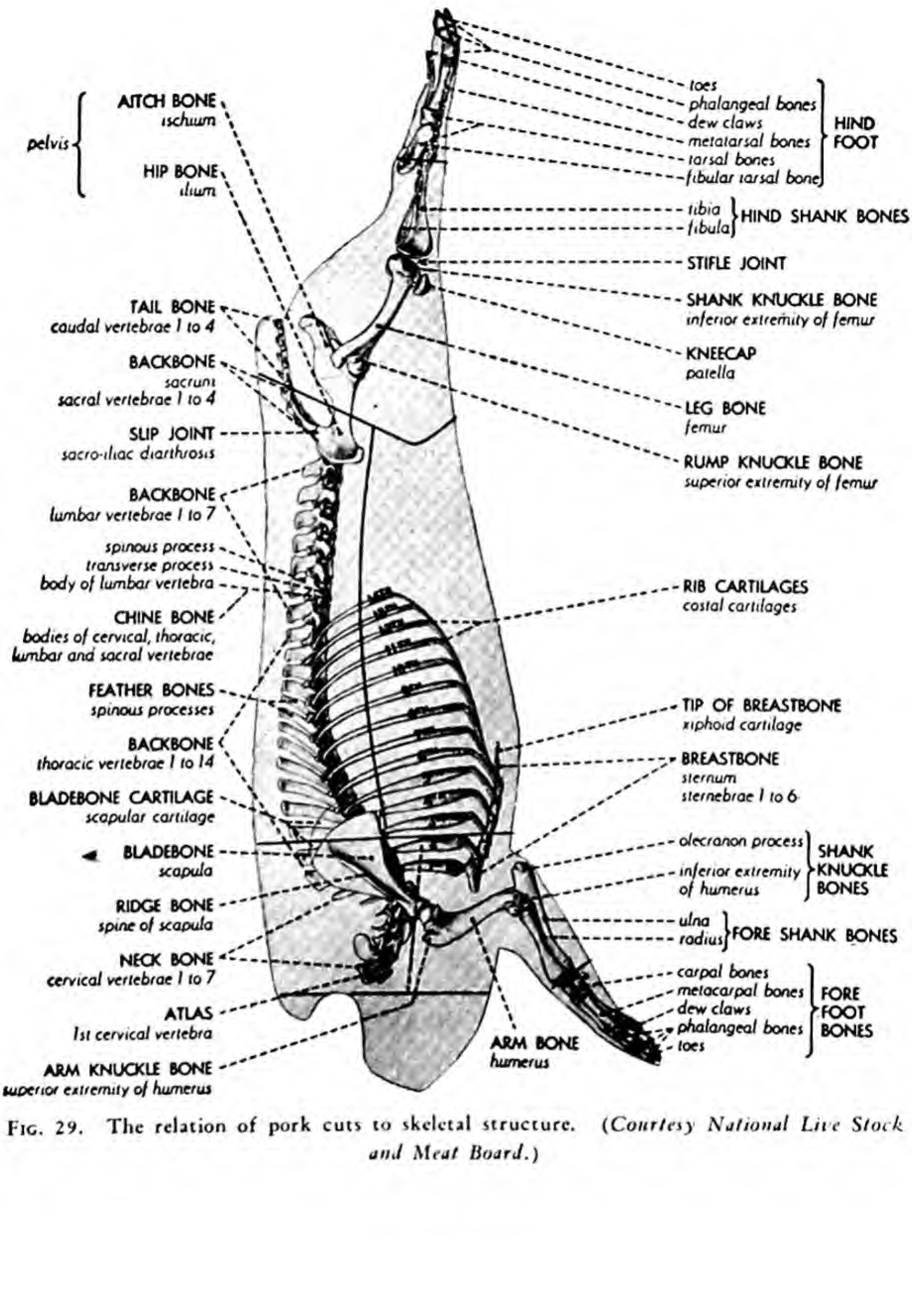
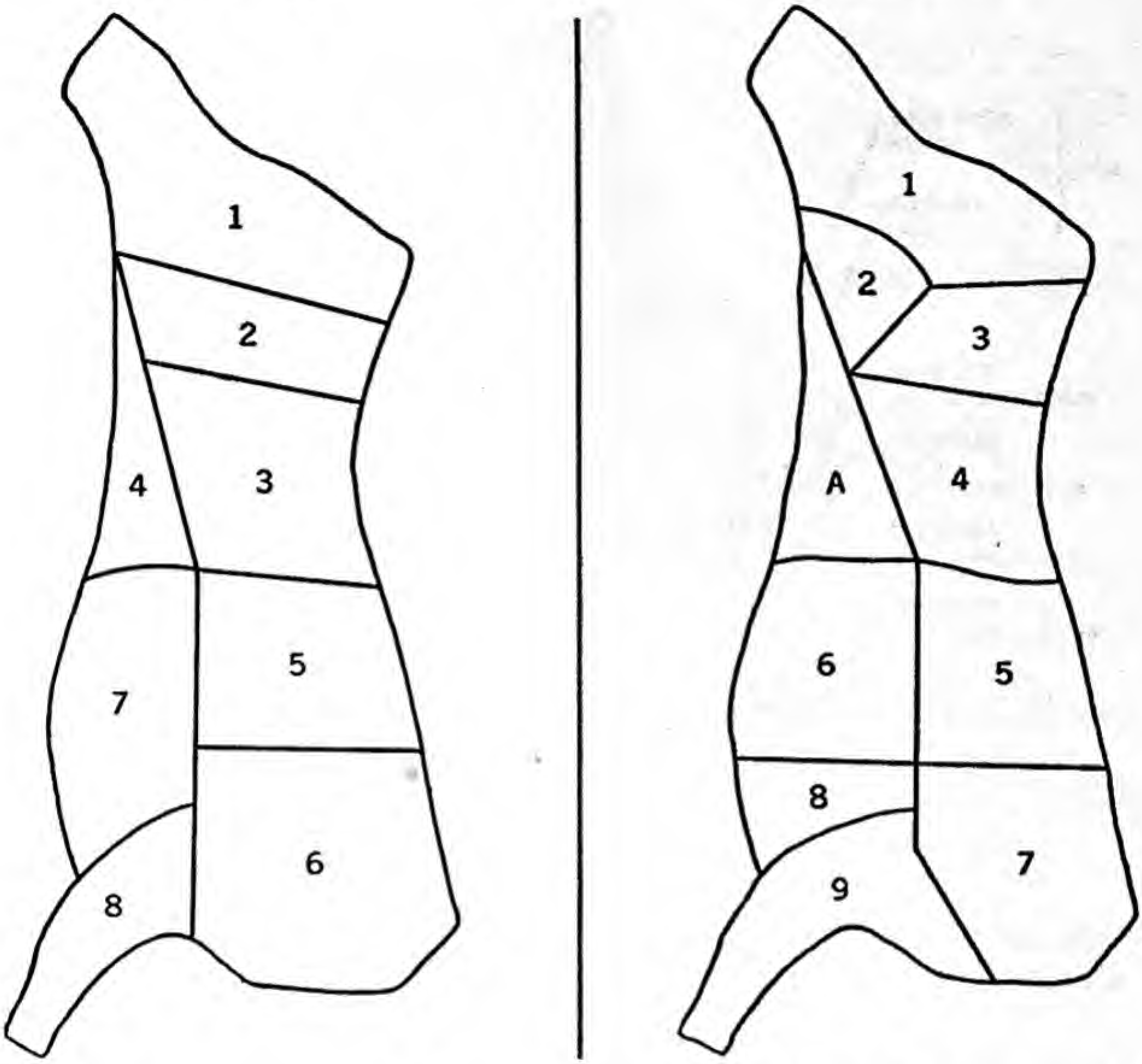


FIG. 29. The relation of pork cuts to skeletal structure. (*Courtesy National Live Stock and Meat Board.*)

CHICAGO NEW YORK



Chicago

#1 Round	24%
#2 Loin End	8%
#3 Short Loin	8%
#4 Flank	4%
(Suet)	4%
Hindquarter Total	48%
#5 Rib (7 ribs)	9%
#6 Chuck (5 ribs)	26%
#7 Plate	13%
#8 Shank	4%
Forequarter Total	52%
Side of Beef Total	100%

12 Ribs on Forequarter

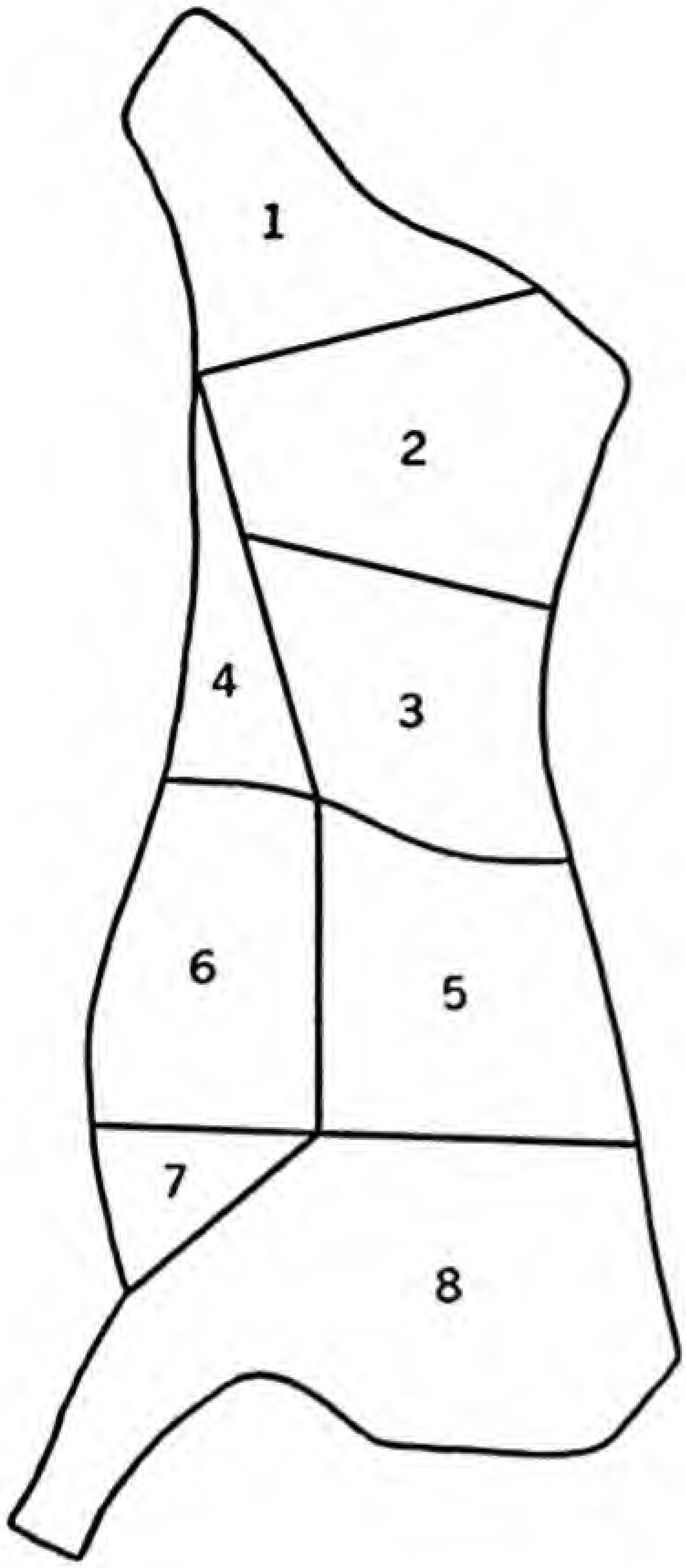
New York

#1 Round (with flank "A")	24%
#2 Top Sirloin (or Butt)	6%
#3 Short Hip	6%
(N.Y. full Hip - #2 & #3)	
#4 Short Loin (Incl. Suet)	12%
Hindquarter Total	48%
#5 Rib (8 ribs)	10%
#6 Plate	10%
#7 Short Chuck (4 ribs)	16%
(N.Y. Full Chuck, #7, #8, #9.)	
#8 Brisket	8%
#9 Shoulder	8%
Forequarter Total	52%
Side of Beef Total	100%

12 Ribs on Forequarter

FIG. 30. Standard beef cuts. (*Courtesy Swift and Co., Chicago, Ill.*)

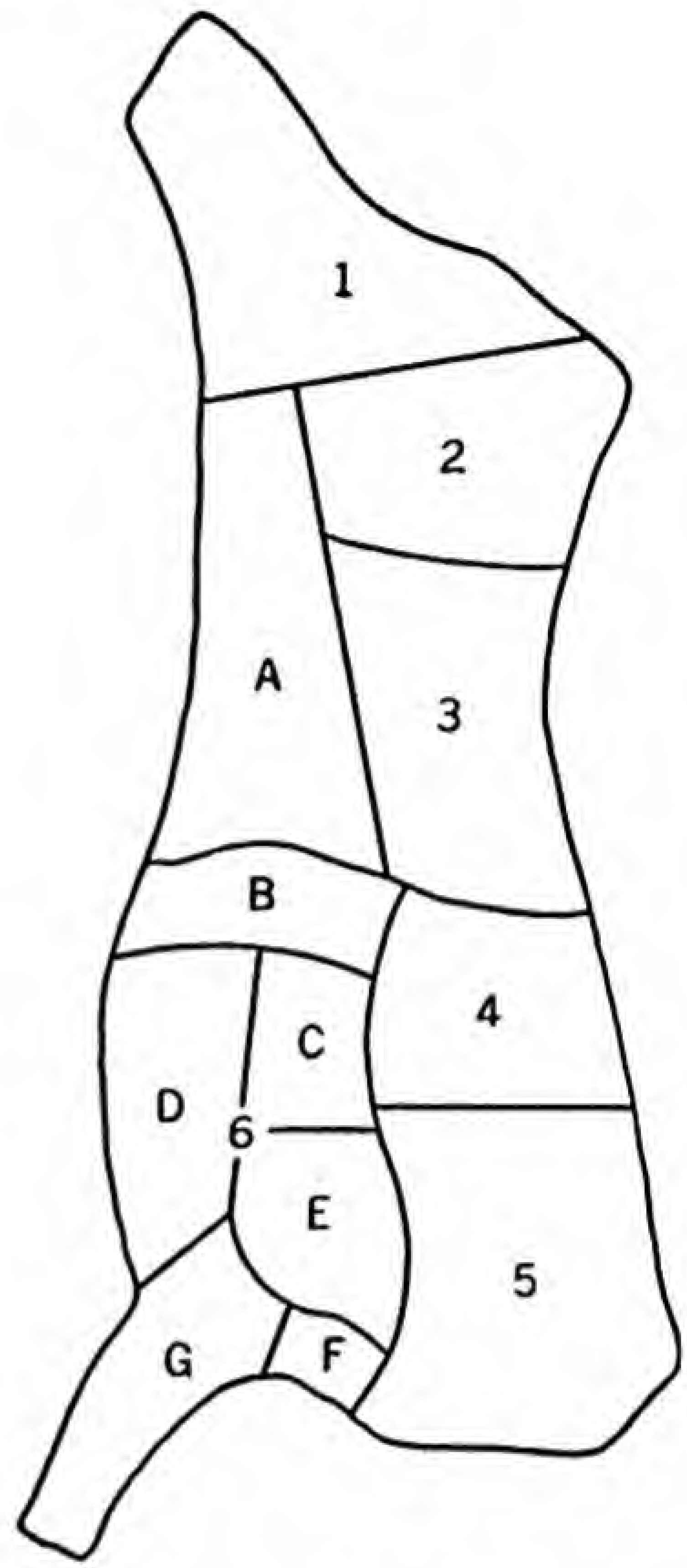
PHILADELPHIA



#1 Round	18%
#2 Rump	12%
#3 Loin (Incl. Suet)	12%
#4 Flank	4%
Hindquarter Total	46%
#5 Rib (8 ribs)	10%
#6 Plate	10%
#7 Butt	4%
#8 Chuck (5 ribs)	30%
Forequarter Total	54%
Side of Beef Total	100%

13 Ribs on Forequarter

BOSTON



#1 Round (with flank "A")	23%
#2 Rump	11%
#3 Loin (3 ribs)	15%
Cod Fat	2%
Hindquarter Total	51%
#4 Rib (5 ribs)	6%
#5 Chuck (5 ribs)	18%
#6 Rattle, includes	25%
Navel B Shoulder E	
Middle Rib C Sticker F	
Brisket D Shin G	
Forequarter Total	49%
Side of Beef Total	100%

10 Ribs on Forequarter

FIG. 30. *Continued.*

In addition to the usual muscle cuts, the edible organs and unusual cuts include the following:

Brain	Sweetbreads (thymus glands of calves)
Tongue	Tripe (plain tripe—the first stomach
Heart	of beef; honeycomb tripe—second
Liver	stomach of beef)
Kidneys	Oxtail

Nutritive Quality of Meat in Unprocessed Forms

The nutritive contributions of meat are shown in Table XXXIX. The energy value of meat varies greatly with its fat content. About 3 ounces is an average serving of cooked muscle meats (about 4 ounces before cooking). Muscle tissue except that containing much fat dispersed among the fibers (pork and salmon in particular) averages about 150 calories per serving, and about 18 grams of protein. If all the visible fat is rejected, the energy value is reduced.

Meat of average leanness provides more protein per serving than any other commonly eaten food, about one-fourth of the *Recommended Allowance* for a physically active man. The fiber proteins are complete, well-adapted to body building, and suitable as a supplement to the cereal proteins. The connective tissue proteins, however, are incomplete, and when present in large proportions they lower the biological value of the whole.

The muscles of domestic animals and birds are among our richer sources of iron, but liver and kidney furnish more than twice as much as muscle. Experiments show that either the iron of meat is very well absorbed, or it increases the absorption of that in other foods eaten with it.[2] Clams and oysters are also rich in iron, but fish, lobster, and crabs are low in comparison with muscles of land animals. The sea foods are unique for their iodine value.

Lean muscle meats, liver, and kidney, and heart of domestic animals, are outstanding sources of the vitamin B complex, especially niacin. Pork muscle is remarkable for its thiamine content, containing ten times the amount in beef and poultry and about five times that in veal and lamb. Kidney and liver in general are superior to muscle cuts in the B complex except for the thiamine in pork muscle and heart. The glandular organ cuts are especially high in ribo-

[2] Johnston et al., *J. Nutrition*, 35: 453 (1948).

Table XXXIX. The nutritive contributions of meat and allied foods, given as percentages of the *Recommended Allowances* for a physically active man

[Babcock, *N. J. Agr. Expt. Sta. Bull.* 751 (1950)]

Food, description and measure *	Energy	Protein	Calcium	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Ascorbic acid
	Food nutrients								
Beef, round, medium fat	6	28	1	24	(0) †	5½	9½	31½	0
Veal, leg cutlets, medium fat	5½	28	1	24	(0)	9½	14½	43½	0
Lamb, hind leg	8	25½	1	22½	(0)	10½	12	34½	0
Pork, ham, medium fat	11½	21½	1	19	(0)	49½	10	26½	0
Chicken, roaster	6½	29	1½	12½	(0)	5½	9	53½	(0)
Turkey, medium fat	9	28½	2½	31½	(0)	6	8	53½	(0)
Organs									
Beef kidney	4½	21½	1	66	23	24½	141½	42½	17½
Beef heart, lean	3½	24	1	38½	½	38½	49½	52	8
Beef tongue, medium fat	7	23½	1	23½	(0)	8	16	33½	(0)
Beef liver	4½	28	½	55	878	17½	185	91½	41½
Calf liver	4½	27	½	88½	450	14	173½	107½	48
Pork liver	4½	28	1	150	284	26½	165½	111½	30½
Cod	2½	23½	1	3½	0	4	5	14½	2½
Halibut	4	26½	1½	6	9	4½	3½	61½	....
Mackerel	6½	26½	½	8½	(9)	10	19½	56	....
Salmon, Chinook or King	7½	25	...	7½	6	6½	13	48	12
Clams	2½	18½	(9½)	(58½)	2	6½	10	10½	....
Crabs	3	23	(4)	(6½)	.....	9½	3½	18	....
Lobster	3	23	6	5	.....	8½	3½	12½	....
Oysters	3	14	9½	46½	6½	10	11	8	....
Scallops	2½	21	2½	15	0	(2½)	5½	9½	....

* All measures given as edible portion raw, 100 grams (about 3½ ounces).

† Imputed figures in parentheses.

flavin. Except for liver, meat is a negligible source of ascorbic acid after it is cooked.

Muscles contain little or no vitamin A. There is a small amount in the flesh of oily fish, but the outstanding sources among all foods are liver and kidney. There is considerable variation among different samples because food and age of the animal influence its liver storage of vitamin A. Liver of younger animals tends to have less than that of the older. Probably all livers as well as the body oils of certain fishes, including salmon, contain significant amounts of vitamin D. The amount of vitamin D in liver varies from 10 to 70 IU per 3½-ounce serving, depending on the species of animal and other factors.[3] Red salmon has been found to have about 800 IU per 3½-ounce serving, Pink 625, Chinook 275, and Chum 225.[4] Of course, this is of no importance in meeting the needs of infants and most others who require large amounts of this vitamin.

In general, the outstanding contributions of flesh foods are their protein, iron, thiamine, riboflavin, and niacin. They do not furnish much calcium, ascorbic acid, or vitamin A, since so few people eat liver frequently. In their 1948 survey of diets of urban families, the BHNHE found that meat, poultry, and fish provided 13.9 per cent of the energy, 29.4 per cent of the protein, 2.1 per cent of the calcium, 24.6 per cent of the iron, 8.4 per cent of the vitamin A, 25.1 per cent of the thiamine, 16.9 per cent of the riboflavin, 43.8 per cent of the niacin, and 1.2 per cent of the ascorbic acid consumed.[5]

For many years the idea that white meat is superior to red meat, especially for invalids, has been generally held. The only difference of any importance between them seems to be in their connective-tissue content, red meat containing more. This makes it slightly tougher and somewhat less valuable for tissue building, though the latter fact has little practical significance.

Many people believe that flesh foods are concentrated nutrients which have peculiar value in nutrition. It is true that the bodies of other animals resemble our own in composition, and, to the extent that our food is used for tissue building, meat represents a well-selected supply of amino acids gathered from the plant world. However, as we eat meat, confining our consumption rather exclusively

[3] DeVaney and Munsell, *J. Home Econ.*, 27: 240 (1935).

[4] Munsell, *Milbank Mem. Fund. Quart.*, 21: 102 (1943).

[5] U.S.D.A., "1948 Food Consumption Surveys," *Prelim. Rept.* 12 (1949).

to the muscles, meat is deficient in important nutritive essentials, including calcium, vitamin A, and vitamin C. Such peoples as the Eskimos do not limit themselves in this way, but rather generally eat organs, blood, bone marrow, etc., and these in the raw state. This habit makes meat a much more adequate diet for them than it is for us.

We like to eat meat because it is stimulating, creates a feeling of well-being, and has enjoyable, appetizing flavors. But nine-tenths or more of the calorie value of the food needed by an adult is required for energy rather than tissue building. Fats and carbohydrates meet energy requirements more efficiently and economically than protein.

On the other hand, certain cults of faddists advocate abstaining from the eating of meat in any form. Some attribute kidney disease and a host of other ailments to its consumption. There is no experimental evidence that even unusually high consumption of meat *causes* any disease. As we eat it, it is an unbalanced food but one that forms a valuable part of a properly chosen diet for its contributions of protein, iron, and the vitamin B complex.

Growing children and pregnant and lactating women have relatively high requirements for the nutrients supplied by meat and respond with measurable physiological gains when they receive it in approximately the amounts specified in the *Moderate Cost Food Plan* as compared with very low amounts.

When two groups of institutional children of similarly poor nutritional status at the beginning of the experiment were given diets which met *Recommended Allowances* for individual nutrients but which in the one case included 2 servings of meat per week and in the other 10 servings of meat, pronounced differences appeared during a 14-month period. In each case one-tenth of the meat was in the form of liver. The low-meat group received legumes and other vegetable proteins to equal the extra amount in the high-meat diet. The children on the high-meat diet had superior skins, tongue configurations, skeletal mineralization, growth, hemoglobin, blood vitamin A and protein values, higher urinary excretions of thiamine and riboflavin, better dark adaptation, and less fatigue. Reversing the diets between the two groups for a second 14-month period was associated with a reversal in physical superiority, according to the same criteria.[6]

[6] Mack, *J. Am. Dietet. Assoc.*, 25: 943 (1949).

In another investigation, women in the last 4 months of pregnancy who received a 5-ounce serving of meat daily in addition to their self-chosen diets for 7 months had higher hemoglobin values, less edema, and better success in lactation than similar women who received either no supplement or a supplement of vitamin B complex.[7]

Digestibility of Meat in Unprocessed Forms

To the extent that rapidity of hydrolysis in a test tube is an adequate criterion of speed of human digestion, experiments show that the most rapidly digested meat is that which is roasted or grilled until it barely retains some red color on a cut moist surface. When the fibers are hardened by prolonged heating, the rate is retarded, but raw meat is the slowest of all.[8] This may indicate that rare-done, minced roasts should be recommended for persons with weak digestions. The slowness with which raw meat is attacked by the digestive enzymes is perhaps explained by the antienzyme properties of unheated tissue.

Sanitary Quality of Meat in Unprocessed Forms

Of all foods, meat, along with milk, is the most subject to contaminations which may make it dangerous for human consumption. Animals are subject to many diseases which may render their flesh unfit for human consumption. Federal meat inspection regulations specify some seventeen diseases which may make animals entirely unfit for food, and another dozen or more, which, if in an advanced stage, may also cause them to be unfit. Pork and beef tapeworm infestations are rather uncommon in the United States, but, as stated in Chapter 3, pork is frequently infected with *Trichinellae*.

Meats are also media adapted to harboring germs of human diseases or toxin-producing organisms with which they may become contaminated during unsanitary handling. Among these organisms are the food-poisoning *Staphylococci* which produce a toxin that is not destroyed in cooking. Ground meats should be handled especially carefully because contamination is spread throughout the entire mass. Inspection of slaughterhouses and meat packing establishments to

[7] Leverton and McMillan, *J. Am. Med. Assoc.*, 130: 134 (1946).

[8] Clifford, *Biochem. J.*, 24: 1728 (1930).

ensure exclusion of flies and general cleanliness should always be required. Sulfites are occasionally employed as a preservative in such products, but their use in meat is illegal because they destroy the odor of putrefaction and restore the color to that of red fresh meat. Thus they help to conceal genuine unwholesomeness.

Meat will not long retain its freshness under ordinary conditions for two reasons: (1) Self-contained enzymes will partially digest it, a process known as autolysis. This causes meat to become less firm and finally to break down to a semiliquid mass. (2) Before this type of decomposition has proceeded to any extent, bacteria with which the flesh is usually contaminated cause putrefaction and the development of disagreeable odors and flavors.

Although meat which is contaminated as a result of disease of the animal or of contact with insects, etc., does not always cause illness after it is cooked, consumers in general expect certain esthetic standards in the handling of these products. Also, because the idea of eating unborn or immature animals is repellent, in most places it is illegal to sell veal that is less than three weeks old.

In the United States, federal meat inspection laws apply to all cattle, sheep, swine, and goat carcasses and products if they enter into interstate commerce, when slaughter did not take place on the farm where the animal was produced. The inspected meats are passed upon by inspectors trained to recognize unwholesome meats, who also supervise the sanitation of the packing plant and its employees. Most cities regulate the sanitary conditions of the places where meats are sold. Thirty per cent of all meat is not inspected, however, because it is from animals slaughtered in small establishments for local consumption, or on farms. All federally inspected meat is stamped, "Inspected and Passed," and the consumer should learn to demand this insurance of safety. Under federal meat inspection, beef containing tapeworm larvae is held under low temperature refrigeration which causes their death before it is sold.[9] Products containing pork, such as frankfurters, bologna, and other sausages, are processed with sufficient heat to ensure the killing of *Trichinellae*. But adequate cooking is still the only practical method of eliminating the danger of acquiring trichinosis from infected raw pork.

Although poultry was not placed under the original meat inspection laws, the Bureau of Agricultural Economics has been authorized

[9] Schwartz, *Am. J. Public Health*, 29: 1133 (1939).

to inspect and certify dressed poultry for condition and wholesomeness. Many packers of poultry products and some cities are availing themselves of this service. Inspected products can be labeled, "Inspected and Certified by the Bureau of Agricultural Economics, U. S. Department of Agriculture."

Flesh foods which are to be kept for any considerable period must be sterilized or almost sterilized and sealed as in canning, or they must be frozen, dried, or cured. All these processes either destroy the autolytic enzymes and bacteria causing decomposition or the formation of toxins, or produce conditions unfavorable for their activity, or both.

Fish are particularly susceptible to contamination and spoilage. Although the flesh of healthy fish is free from bacteria when they are caught, bacteria in their intestines and in the slime on boats or in dressing plants with which they come in contact develop rapidly and penetrate the muscles after they are killed. Many of these germs come from sea water and thrive at cool temperatures so that fish must be kept near freezing to prevent early spoilage. Cod fillets, for example, keep twice as long at 32 degrees F. (0 degree C.) as at 37 degrees F. (2.8 degrees C.).[10]

Bacteriological control of the handling and production of shellfish is particularly important, because shellfish prefer localities where rivers enter the ocean. Such streams often carry sewage bearing pathogenic bacteria with which oysters and clams may become infected. When these products are eaten raw, infection may result. It has been repeatedly established that oysters may be the cause of typhoid infection.

For short-time household storage, all fresh meats, poultry, and fish should be lightly covered with wax paper and placed in the coldest part of the refrigerator, 40 degrees F. (4.4 degrees C.), or lower if possible. Ground meats, poultry, fish, and variety meats should preferably be frozen if they must be held more than 24 hours. Roasts can be held 2 to 5 days, the shorter time for pork and the longer for beef. Ham and bacon may be kept two weeks.

Palatability of Meat in Unprocessed Forms

The qualities that enter into the palatability of meat include (1) tenderness, (2) flavor, (3) appearance, especially color, and (4)

[10] Hess, *Food Technol.*, 4: 477 (1950).

juiciness. In many foods, processing is more important in controlling palatability than ordinary variations in the quality of the raw materials. But, whereas meat can be ruined through faulty preparation, no amount of skill in processing can raise the palatability of some samples to that of others. For this reason, it is especially desirable to know something about the factors other than processing which are associated with variation in its palatability.

Tenderness in Meat

Tenderness in meat is the relative ease with which it can be masticated. Properties of the unprocessed meat which are related to tenderness in the cooked product are (*a*) the kind and amount of connective tissue, (*b*) the quality and distribution of the muscle fibers, (*c*) the amount and distribution of the fat, and (*d*) ripeness.

The Kind and Amount of Connective Tissue. As noted previously, there are two kinds of connective tissues in meat, the white, which is principally collagen, and the yellow, which is principally elastin. Although yellow connective tissue may be much less tough than white connective tissue when it is raw, it is changed but little during cooking because heat has little action on elastin. On the other hand, heat changes collagen to gelatin, which is, of course, not tough. Consequently, white connective tissue can be greatly altered during cooking.

Both the kinds and amounts of connective tissue vary with age, sex, and species of the animal, and also with the cut. Pork has less connective tissue than beef. Fish are always tender. Probably on account of the buoyant action of the water, fish do not need the strength and firmness contributed by connective tissue, and little develops. The flesh of young animals contains less connective tissue than that of old. Males tend to have more than females, but the removal of the testes at an early age, a procedure known as castration, eliminates this difference. Thus capons and steers have much tenderer flesh than roosters and bulls. The more exercised cuts within the animal develop more connective tissue, especially of the type high in elastin. Thus cuts along the back tend to be more tender than those from the neck and legs. The effects of some of these factors are shown in Table XL.

Appearance, texture, and firmness of the lean, qualities commonly used in judging meat on the market, give little indication of tenderness so far as it is related to the connective tissue. The best criteria

Table XL. The composition of the connective tissue in different cuts of a young steer, weight 900 pounds

[After Mitchell et al., 1928]

Cut	Collagen N in per cent of total nitrogen	Elastin N in per cent of total nitrogen
Round steak	12.7	0.15
Porterhouse steak	12.0	0.05
Sirloin steak	12.4	0.02
Ribs (9, 10, 11) eye	8.7	0.03
Chuck ribs (2, 3)	14.8	0.26
Fore shank	22.0	0.10
Navel	15.7	1.00
Tenderloin	8.2	0.07

of relative amounts of connective tissue in a particular kind of meat at the market are the cut and the age of the animal.

In a study of the tenderness of beef in relation to the particular muscle and the age of the animal it was found that in five different age groups, the muscles could be divided according to four different degrees of tenderness. Thus the order of tenderness from least to greatest was (1) neck and fore shank, (2) round, (3) chuck at the third rib and across the humerus bone to the eighth rib, short loin, and loin end, and (4) tenderloin. The variations in veal and 500-pound steer calves were less than in more mature animals but, as the age increased, tenderness decreased in each muscle.[11]

At the market the meat buyer can judge to some degree the age of the animal from which a meat cut has come by color, the muscles of younger animals tending to be lighter red, the bones pinker on cut ends, and the fat whiter in comparison with cuts from older animals.

The Quality and Distribution of Muscle Fibers. Some muscle fibers are dense and stronger or coarser than others and tend to result in tougher meat. Age and activity may be factors increasing toughness in this way. The number of muscle fibers is believed to be unchanged after birth—those present at that time simply grow in size. Also, animals of the female sex have finer-grained flesh than older animals of either sex or males. Castration of males makes them resemble females in this respect; thus capons or steers have finer-grained flesh than bulls or roosters. Coarse grain in meat is usually associated with a lower degree of tenderness.

11 Hiner and Hankins, *J. Animal Sci.*, 9: 347 (1950).

Evidence has been accumulated which indicates that heredity is a factor in the tenderness of meat, certain family lines of animals tending to give flesh that is tenderer than that from other lines. This points to the desirability of selection and propagation of the better strains. It will be of interest to discover whether heredity controls tenderness through differences in the connective tissue or in the muscle fibers, or in some other way.

Distribution of muscle fibers affects tenderness because cooked meat should be sliced across the grain to make it easier to chew. When the fibers do not run parallel, a slice will contain some short sections of fiber and some which are longer. In certain parts of the animal, the shoulder, for example, there are many muscles which run in crisscross directions. Even when the connective tissue is softened by cooking, such meat is more difficult to masticate than that with muscles running in the same direction.

The Amount and Distribution of Fat. When the connective tissue surrounding the bundles of muscle fibers is dotted with many fat deposits, the flesh is said to be well-marbled and is expected to be tenderer than it would be if the fat were absent, though the experimental evidence on this point is not conclusive.[12]

This scattered fat is especially desired in older animals. Unfortunately it is not formed to any great extent until the outside of the carcass is covered with a heavy coating of fat, which is not usually eaten and which contributes little to the quality of the meat except as it adds to flavor during cooking. All fat is relatively expensive to produce, and this scattered form is especially costly.

Ripeness. When an animal is first killed, the muscle fibers are soft and flabby. The individual cells do not cease to function as soon as loss in coordination produces the death of the organism as a whole. Active cells produce lactic acid and carbon dioxide, which are not removed in the dead animal. As these accumulate, the muscle fibers develop a strong acidity, and tend to imbibe the water from the body fluids. This causes them to swell and become taut and hard, a condition known as *rigor mortis.* These changes may take place in a few minutes or not for an hour or more after death, the rate being faster ~~when the animal was exercised~~ just before death.

After a variable period, never more than a few days, the meat passes to a third stage in which it becomes soft and tenderer than it was at the death of the animal. According to one theory, the

[12] Cover et al., *Tex. Agr. Expt. Sta. Bull.* 661 (1944).

disappearance of rigor is due to some coagulation of the muscle protein, which finally takes place as the acid accumulates, and subsequent syneresis.

In cooking tests on beef, it has been found that steaks fried in deep fat are tender by the shear test if cooked immediately after slaughter (before rigor sets in), but less tender if cooking occurs after the meat has been in cold storage up to 24 hours. It returns to its original tenderness after about 6 days of cold storage when presumably rigor has passed. The same experimenters found that roasts were least tender if cooked immediately after slaughter and became increasingly tender as the time of cold storage lengthened. The absence of tenderness in roasts immediately after slaughter was attributed to the development of rigor during the first part of the roasting time as a result of the slow rate of heat penetration. This did not happen with steaks because the pieces of meat were much thinner and the rate of heat penetration much faster.[13]

Thus it appears to be preferable to allow meat to pass through the stage of rigor if it consists of cuts suitable for dry heat cooking, except for steaks cooked immediately after slaughter. After rigor passes, an additional period of ripening by enzyme action increases tenderness, flavor, and apparent juiciness. Commercially, meat, particularly beef of the better grades, is ripened for special demand by being held in a cooler at 34 to 36 degrees F. (1 to 2 degrees C.) for 2 to 6 weeks, the time depending upon the degree of ripening desired. Beef, however, may be in good condition for cooking within a week or 10 days after killing, and pork, which develops little rigor and is naturally more tender, is suitable for use after 2 or 3 days in the cooler. According to a study of the effects of ripening on tenderness of leg of lamb, it was found that 7 to 10 days of cold storage produced a noticeable improvement, but that a longer period of holding resulted in little additional change. The increase in tenderness during ripening is in part a result of a decrease in collagen, since it has been found that the collagen content of beef ripened 30 days was but 60 per cent of that found in fresh meat. Elastin is also reduced.

Because enzyme activity is thus accelerated, it is possible to ripen meat in a short time (2 days) at high temperatures [60 degrees F. (15.7 degrees C.)] if ultraviolet lights are employed to restrict microbial growth.

13 Paul et al., *Food Res.*, 17: 504 (1952).

The protein-splitting enzyme from pineapple, *bromelin*, is employed commercially to tenderize sausage casings, and another, *papain*, from papaya leaves, is present in mixtures sold for household application to tough meats. When painted on the surface of the meat and held at room temperatures for 30 minutes these preparations have only surface action and hence are of little practical value.[14a] However, when they are injected below the surface by "forking" and allowed to stand at room temperature for 1 hour per inch of thickness of the meat cut, a definite increase in tenderness of the cooked product can be noted.[14b] This procedure may be subject to sanitary hazards, depending upon the conditions of previous holding of the meat as well as the period of treatment required for thick cuts.

In general, the kind and amount of connective tissue, together with the effects of ripening upon that from tougher animals such as beef, are the most important factors determining the tenderness of meat before it is cooked. When the amount of connective tissue is high it is necessary to use moist heating (heating in a covered container with or without added water) to change the collagen and make the meat suitably tender if it is to be cooked in the piece, that is, without some form of grinding or "cubing." When the amount of connective tissue is low, short cooking and dry heat methods can be employed.

The Flavor of Meat

The flavor of raw lean meat is present for the most part in the juice, rather than in the fiber, and is due to the saltiness and sweetness of the blood rather than to the nitrogenous extractives creatine and creatinine to which it has been attributed in the past. This is true of the meat of birds and fish as well as that of domestic animals.[15] Superimposed on this basic flavor are others which are related to:

Species: Each species has a more or less distinctive flavor.

Sex: Males, except when castrated, are more strongly flavored than females.

Age: Older animals are more highly flavored. Young flesh is often considered insipid. It is said that steers should be at least

[14a] Gottschall and Kies, *Food Res.*, 7: 373 (1942).

[14b] Hay et al., *Food Technol.*, 7: 217 (1953).

[15] Crocker, *Food Res.*, 13: 179 (1948).

20 months old and preferably 30 to give roasts having the most desirable flavor.

Exercise: More highly exercised muscles have meat of higher flavor. For example, chicken breast has much less flavor than chicken leg. Thus tougher cuts may be superior to tender cuts in flavor.

Ripeness: As meat ripens, the flavoring constituents increase until the flesh may be called "high." Epicures prefer meat that has undergone a considerable amount of this change. As nearly a "sea-fresh" flavor as possible for fish is preferred by those who live near the coast—the only ripened fish being such appetizers as anchovy fillets and specially marinated kinds. Fish have the freshest flavor while they are still in rigor which varies from a few minutes to about 10 hours after killing, depending upon the species, exercise before killing, and conditions of storage after killing, as with other meats. Loss of fresh flavor in fish is more noticeable after cooking than before and is apparent in cod after one day at 32 degrees F. (0 degree C.).[16] Quick freezing is the best method of retaining fresh flavor away from the coast. In selecting fresh fish at the market, one should look for firm flesh, red gills, and bright, full eyes.

Feed: Cereal-fed domestic animals have mild-flavored flesh as a rule. The sulfur compounds in wild onions and garlic may pass over into animal flesh and give it an unpleasant taste. The pronounced flavors of game animals are in part due to the variety of their feed or to its peculiar nature. Canvasback ducks are considered choice when they have been eating wild celery. A western species of game bird, known as the sage chicken because it feeds on sage brush, has a flesh mildly flavored with sage. Domestic animals may be fed on special foods to produce certain flavors in their meat; thus turkeys are sometimes given celery and chestnuts for this purpose. Objectionable flavors may also be contributed by feeds such as fish meal.[17]

At least some of these superimposed flavors, especially those from feed, probably reside primarily in the fat. During storage, oxidation of the fat itself produces in time the undesirable changes in flavor associated with rancidity. This is a special problem with pork

[16] Hess, *Food Technol.*, 4: 477 (1950).
[17] Vestal et al., *J. Animal Sci.*, 4: 63 (1945).

and explains why unsliced bacon with less surface exposed to the air, keeps better than the sliced product.

Musty or "earthy" odors which occasionally develop in raw meat are caused by the growth of microorganisms. Apparently they are harmless but they affect flavor undesirably even after cooking.[18]

The Color of Meat

The red color of raw meat is caused by protein pigments, the hemoglobin of the blood, and the myoglobin of the muscle. It has been estimated that 90 per cent of the pigments present in fresh meat is myoglobin which differs from hemoglobin in structure and properties. The intensity of color in the common meats varies from a pale red or gray-red to a dark red, and is affected by the following factors:

Species of Animal: Beef is redder than pork.

Age of the Animal: Older meat is darker than that from younger animals.

Exercise: Muscles of the type which receive more exercise tend to be darker red in color; for example, legs as compared with breast of chicken.

Feed: The color of the flesh varies somewhat with the feed.

Exposure of Cut Surfaces to Air: When meat is first cut, it develops a bright red color as a result of formation of oxymyoglobin. When the cut surface stands and dehydrates, it darkens. This darkening is considered unattractive and is the biggest problem in selling packaged meat.

The color of the fat in meats varies from white to a deep yellow according to the amount of carotene pigments which it contains. The pigments are derived from the food of the animal; some species or breeds tend to deposit them in their body fats to a greater extent than others. Grass-fed animals have yellower fat than those fed grain; also older animals have yellower fat.

The color of both fat and lean of meat is ordinarily considered a valuable criterion of palatability. Experimenters say, however, that the color of the raw beef muscle has no relation to the color, quality, or palatability of the cooked product. We do not know of careful studies of the relationships in other species. Color of fat, so far as it is affected by age, is a somewhat more reliable indicator of quality of the meat as a whole.

18 Jensen, *Food Res.*, 13: 89 (1948).

Grading of Meat

The federal government has established retail grades for beef, calf, veal, mutton, lamb, and poultry. Retail grades for pork have not been established because most of the pork comes from young animals and varies less in quality. The established grades for the meat animals are based on characteristics designated as *conformation, finish,* and *quality*. Conformation refers to the build or shape of the animal, finish to the amount and distribution of the fat, and quality to the texture of the lean, hardness and color of the fat, etc. In beef, carcasses are also classified according to age and sex (steer, heifer, cow, stag, bull). Meat which is graded by federal inspectors may be stamped with the appropriate grade name, for example, U. S. Prime, for the best grade of beef, but this is voluntary except where it is required by city ordinances or when in an emergency it is required nationally to supplement price control.

Beef grades which appear on the retail market are Prime, Choice, Good, Commercial, and Utility.

U. S. Prime Beef is from well-fed, usually young, steers and heifers. It has a fairly thick covering of fat and abundant marbling. More of the cuts are suitable for dry heat cooking than those of any other grade and give the highest eating quality.

U. S. Choice Beef carries less fat than prime but is well-covered and marbled. Many of the cuts are of excellent eating quality when cooked by dry heat.

U. S. Good Beef has less surface fat and marbling than Choice but is from young animals and, although less juicy than Prime or Choice, has many tender cuts.

U. S. Commercial Beef comes largely from older animals, and some cuts, which could be cooked by dry heat if of Prime or Choice grade, require moist heat to develop tenderness. Beef of this grade has a high proportion of lean.

U. S. Utility Beef comes from young animals of poor quality or from older cattle, is low in fat, and lacks natural tenderness and juiciness. Again, there is a large proportion of lean, and, with moist heat to develop tenderness in most cuts, this is a satisfactory product.

"Veal" is now reserved for the meat of the youngest beef animals, those less than 14 weeks old and fed largely on milk. The flesh is fine textured, light pink in color, and mild in flavor. Meat designated as "calf" comes from older animals which have not yet taken on beef characteristics. The meat is firmer and coarser in texture

than veal, deeper red in color, and richer in fat. Grades for veal and calf have the same names as those for beef.

Lamb and mutton are graded *Prime, Choice, Good,* and *Utility.*

Grading of poultry is also voluntary, but when a bird is stamped with U. S. grade designations it must meet the specifications for the grade. High-quality birds which are well-fleshed and have fat well distributed under the skin, with no deformities such as a crooked breastbone and few if any tears, bruises, or pin feathers, qualify for *U. S. Grade A. U. S. Grade B* are somewhat lower in these characteristics, and birds of *C* quality, which are still lower, are not individually labeled. Classes of chickens include (1) *broilers* or *fryers,* (2) *roasters,* (3) *capons,* and (4) *hens, stewing chickens* or *fowl. Dressed* birds have been bled and picked but not drawn. *Ready-to-cook* are those which have been fully drawn or eviscerated.

In a general way, grades correlate with palatability because the properties of meat which control tenderness, flavor, juiciness, and color, as discussed above, are associated in turn with species, age, sex, "finish," "form," and "quality" of the animal. Grade has been found to correlate particularly well with tenderness, although the emphasis put upon marbling is not justified so far as this palatability quality is concerned. The relationship between grade and amount of connective tissue is the important one.[19] As is true of grading of other foods, these ratings are more closely related to palatability than to other criteria for choice of foods, and the consumer's aim should be not to purchase the highest available grade but the one which is acceptable for the intended use and which is offered at an appropriate price.

Economy of Meat in Unprocessed Forms

The relative cost of any flesh food in terms of its nutritional values may be judged by comparing it with other sources of animal protein. (See Table XXXIII for approximate animal protein equivalents.) As brought out previously, milk proteins nearly always cost less. Basically this is because the dairy cow is a more efficient converter of plant feeds into milk proteins than poultry is into eggs or any domestic animal is into meat. Usually the only competitor of milk in economy of protein is fresh fish in areas where it can be purchased before costs of labor, preservation, and

[19] Husaini et al., *Food Technol.*, 4: 313 (1950).

transportation have increased its price to consumers beyond that of milk; possibly some kinds of canned or smoked fish also can compete. A moderate consumption of meat is desirable for reasons connected with its nutritive quality as discussed previously, but money spent for it should not be subtracted from that required to purchase recommended amounts of milk or its equivalent products.

Hogs are the most efficient meat builders among domestic meat animals, and hence pork is usually a better buy than beef or lamb. Turkeys hold this rank among the different kinds of poultry.

In evaluating the relative economy of flesh foods themselves, the best criterion is price per unit of edible lean meat. The proportion of edible lean varies greatly with the species, the cut, the grade, and the amount of trimming at the market.

At the University of Illinois, cuts of beef of *Choice* grade (*Good* grade in the pre-1951 designation) were found to have the following approximate percentages of lean.*

100	Flank steak
85	Round, heel of round
75	1st and 2nd chuck ribs
70	Wedge and round bone sirloin steaks, arm
65	3rd, 4th, 5th, and 6th chuck ribs
60	7th and 8th ribs, double-bone sirloin steak, porterhouse, club, and T-bone steak, rump (knuckle out), neck
55	Short plate, 9th and 10th ribs, hip bone
50	Brisket, 11th and 12th ribs
45	Fore shank
40	Flank
30	Hind shank

In lamb cuts of Choice grade, the approximate percentages of lean were: †

65	Leg
60	Shoulder
55	Loin
50	Ribs
45	Breast

Pork cuts contained the following approximate percentages of lean: ‡

* Bull, *Meat for the Table*, McGraw-Hill, New York (1951), p. 186.

† Bull, *ibid.*, p. 196.

‡ Bull, *ibid.*, p. 193.

85	Boston (butt)
65	Loin and ham
60	Picnic and spareribs
45	Bacon
35	Neck bones

In general, cuts containing much bone, and poultry, have a high proportion of waste. Alexander and Schopmeyer found that stewing chicken purchased before evisceration yielded a little less than one-fourth the original weight in the form of cooked muscle.[20] The BHNHE obtained yields of cooked turkey muscle of 34 to 41 per cent of market weight before evisceration, the higher yields coming from hens. The price per pound of meat at the market is so much affected by factors other than the proportion of lean that the careful buyer should weigh values in terms of these findings.

Grade is a factor in economy of meat in two ways—the higher the grade, the higher is the price per pound and the greater is the waste in fat. In the Illinois studies, the lowest grade of beef and lamb yielded the largest proportion of lean. In poultry as well as in domestic animals, the highest grades have a smaller proportion of lean in each pound as purchased.[21]

The yield in servings per pound as purchased can be estimated as follows:

Meat with much bone or gristle—1 to 2 servings.
Examples: shank, brisket, plate, short ribs, spareribs, breast of lamb or veal; poultry (dressed but not eviscerated).

Meat with medium amount of bone—2 to 3 servings.
Examples: whole or end cuts of beef round, veal leg, or shoulder ham with bone in, steaks, chops or rounds from loin, rump or rib; unboned fish.

Meat with little bone—3 to 4 servings.
Examples: center cuts of beef round, pork shoulder or ham, veal and lamb cutlets, chuck.

Meat with no bone—4 servings.
Examples: ground meat, boneless stew meats, liver, kidney, fish fillets; canned meats and fish; cold cuts. The latter may yield more than four servings if they are highly seasoned because this reduces the amount one cares to eat.

Consumers should understand that in paying for high grades of meat and for many cuts in greatest demand they are paying pre-

[20] Alexander and Schopmeyer, *Food Technol.*, 3: 263 (1949).

[21] Alexander et al., *Poultry Sci.*, 30: 187 (1951).

miums for palatability, not nutritional values. If one intends to grind the meat, to cook it by moist heat, or in the case of beef, to dry-cook to the well-done stage, eating satisfaction may often be as great if the more economical lower grades and cheaper cuts are chosen and they are cooked by appropriate moist heat methods. On account of low demand, such organ cuts as the liver of beef, pork, or lamb, and the kidney usually represent "best buys," not only for protein value in comparison with muscle cuts but also for vitamins and iron.

THE COOKING OF MEAT

The major purposes of cooking meat are to enhance palatability by changing color, developing and increasing firmness, and, in the less tender cuts, tenderness of texture, and to improve the sanitary quality.

The General Effects of Heat on Meat

(1) Muscle fiber proteins, (2) connective tissue proteins, (3) color, (4) fat, (5) juiciness, and (6) flavor, in meat, are all changed by heat.

1. *Muscle fiber proteins.* There are four fiber proteins, each with a different coagulation temperature. Coagulation reduces their imbibition capacities and is associated with reduction in diameter of the fibers and increased firmness of the flesh. There is lack of agreement as to when coagulation begins, but the diameter of beef muscle fibers has been found to decrease by as much as 12 to 16 per cent during heating to 136 degrees F. (58 degrees C.).[22] Consequently we may assume that coagulation begins before this point is reached. As the temperature rises, more shrinkage and hardening of the fibers take place. In beef, diameter of the fibers decreases with increased coagulation up to 153 degrees F. (67 degrees C.), but no further shrinkage takes place between 153 degrees F. (67 degrees C.) and 167 degrees F. (75 degrees C.). This is interpreted to mean that shrinkage resulting from coagulation of muscle plasma is complete at 153 degrees F. (67 degrees C.).

Losses of water from the entire piece of meat are small up to an internal temperature of 145 degrees F. (63 degrees C.) and progress during heating to higher temperatures. Because the effect of

[22] Satorius and Child, *Food Res.*, 3: 618 (1938).

heat in hardening muscle fibers is more pronounced than its tenderizing action in muscles that contain little connective tissue, cooking such muscles may decrease their tenderness rather than increase it.

2. *Connective tissue proteins.* The collagen in connective tissue can be converted to gelatin by heat. However, little change is found at 149 degrees F. (65 degrees C.). Thus cooking to rare or medium stages has little tenderizing action. Higher temperatures of heating, boiling or above, or extended heating to such well-done temperatures as 176 degrees F. (80 degrees C.) are required to produce changes of practical significance. Although attainment of relatively high temperatures in the meat increases the ease with which the fibers separate, the effect on the fiber proteins is undesirable. They lose juice, shrink, and become noticeably drier and harder. It has been suggested that the reason braised meat is improved by cooking to 176 to 203 degrees F. (80 to 95 degrees C.) is that the long exposure to relatively high temperatures somewhat softens the hardened fibers.[23]

Although increased hydrogen-ion concentration promotes hydrolysis of collagen, it has not been found possible to demonstrate a measurable increase in tenderness during the usual cooking period in meats cooked in the presence of tomatoes or after soaking in a marinade.[24] This is because the acid penetrates the meat very little in the usual soaking period.

It is obvious that the effects of heating on fiber proteins and on collagen tend to be antagonistic. Whether extended cooking results in increased tenderness depends to some extent upon the amount of collagen in the meat. A cut low in collagen may appear to be toughened by long cooking as a result of the predominance of the effect on the fiber proteins. In cooking 25 separate beef muscles, it was found that most of them became less tender, some did not change significantly, and others became more tender. This was true whether tenderness was rated mechanically by a shear tester or organoleptically by judges who chewed it.[25]

Ramsbottom and Strandine dissected fifty of the larger muscles of beef and classified them with respect to amounts of elastin and collagen and tenderness before and after cooking. They concluded that the commercial practices of devising cutting systems which throw muscles of similar tenderness together should be extended so

[23] Winegarden et al., *Food Res.*, 17: 172 (1952).

[24] Tofts, M.S. Thesis, Iowa State College Library (1940).

[25] Ramsbottom et al., *Food Res.*, 10: 497 (1945).

that tough and tender muscles would not be included in the same cut.[26]

Yellow connective tissue which is high in elastin is not softened by heat as much as the white of the collagenous type. In one test, it took only about one-sixth as much force to shear collagenous connective tissue after cooking as before, but elastin connective tissue still required about half of the original shear pressure.[27]

3. *Color.* Heat begins to alter the color of myoglobin when the temperature reaches about 122 degrees F. (50 degrees C.). The dull bluish-red which is characteristic of the raw meat first changes to a bright rose-red as a result of the formation of oxymyoglobin. In the range of 150 to 155 degrees F. (65 to 68 degrees C.), oxymyoglobin begins to decompose with the formation of hematin and the development of a light pink color. As the heating and decomposition continue, the brown or gray color of well-done meat appears. Particularly in beef which is cooked slowly, this change may be complete at about 158 degrees F. (70 degrees C.), but in other meats under other conditions a higher temperature may be required. Ripening lowers the temperatures at which color changes take place.

4. *Fat.* Meat fat is deposited in connective tissue, on the surface under the skin, in visible masses within the muscles, and in smaller amounts among the bundles of fibers. During cooking it melts, and on cut surfaces or from deeper portions, when the connective tissue softens, escapes to the pan.

5. *Juiciness.* When the fiber proteins coagulate and lose imbibition capacity as their temperature rises, the water which is squeezed out is partly evaporated except when cooking is in a tightly covered pan. The rest is present in the pan. It takes with it minerals, vitamins, flavors, and other substances in true solution and leaves the meat itself drier and less juicy.

The time-temperature combinations employed for cooking largely determine the changes in juiciness of meat during cooking. In general, the higher the heat applied in cooking and the higher the internal temperature reached in the meat, the less juicy the product will be. Decrease in juiciness is not prevented by cooking in water. In fact, as will be shown later, shrinkage is greater when meat is cooked in water or steam than when it is dry cooked. Apparent juiciness does not always correlate closely with actual loss of water

[26] Ramsbottom and Strandine, *Food Res.*, 13: 315 (1948).

[27] Ramsbottom and Strandine, *ibid.*

by the meat, because other factors such as the presence of melted fat among the fibers may disguise the increased dryness of the fiber itself.

6. *Flavor.* Decomposition of fat and protein and probably the browning reaction are among the major changes affecting development of flavor and aroma of meat during cooking. These changes are most marked on the surface where the highest temperatures prevail. Since most of the flavor is in the juice, the greater the shrinkage of meat during cooking, the less flavor it tends to have, except for the effect of browning on surfaces.

The Methods of Cooking Meat

Cooking methods employed with meat are of two basic types: those in which dry heat is applied and those in which moist heat is used. Dry heat methods include (1) roasting, (2) broiling, (3) pan- or griddle-broiling, and (4) frying in shallow or deep fat. Moist heat methods include (1) braising and pressure cooking (cooking in steam), and (2) stewing or "boiling."

Dry heat methods are the more popular of the two types because they develop the meat surface flavor and because they require only a short time with small pieces of tender meat. They are not practical for less tender cuts unless these cuts are ground or tenderized in other mechanical ways such as "cubing." Less tender cuts *can* be made tender by a dry heat method such as roasting, but the time required for heat penetration is relatively long. Thus, in a 176 degree F. (80 degrees C.) oven approximating simmering temperatures in water, it takes 30 hours for meat to lose its pink color.[28]

Water and steam, which are the cooking media in moist heat methods, are much better conductors of heat than air and cause the temperature of the connective tissue to rise to the point where gelatin is formed much more rapidly.

Stages of Doneness in Cooked Meat

In tender meat, doneness is judged largely by the amount of external browning, development of flavor and aroma, internal coagulation of fibers, and change of color. In less tender products, the principal criterion is the development of tenderness as it is associated with the ease of separation of the muscle fibers.

[28] Cover, *Food Res.*, 8: 388 (1943).

The internal changes associated with doneness, especially in tender cuts of beef, correlate with internal temperature so that a thermometer inserted at the center of the thickest portion of the cut affords a more accurate measure of the stage reached than time per pound. (See Fig. 31.) The three stages of doneness commonly differentiated correspond to internal temperatures as follows:

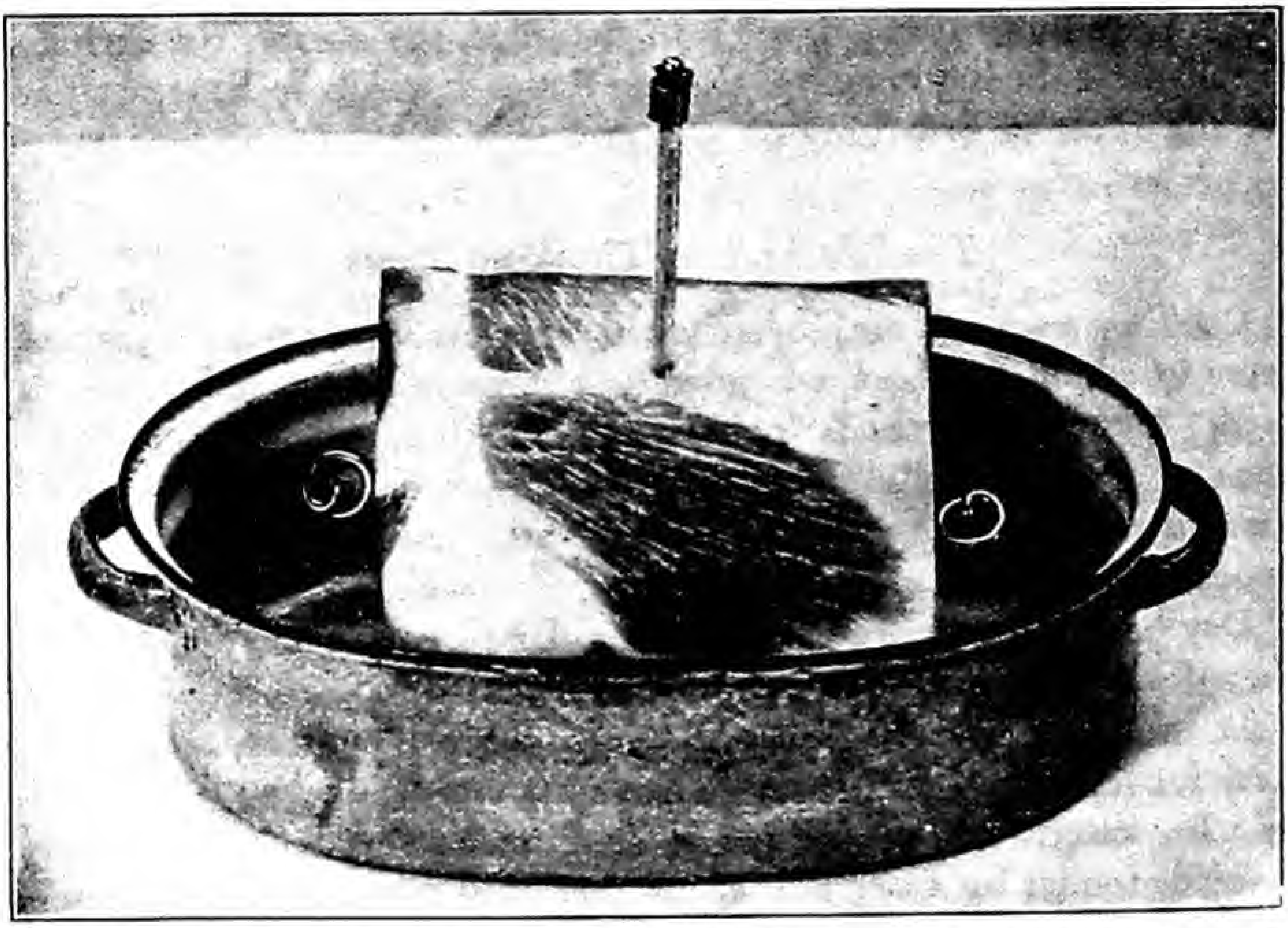


FIG. 31. Pork loin roast ready for the oven, showing thermometer and skewers. (*Courtesy of Alice M. Child.*)

Rare	140 degrees F.	60 degrees C.
Medium	160	71
Well-done		
Beef, veal, cured pork	170	77
Lamb	180	82
Pork	185	85

[Hams labeled "tender" have been sufficiently heated in the smoking process to about 150 degrees F. (65 degrees C.), which is a safe temperature.]

The less tender cuts of beef may reach an interior temperature of 185 degrees F. (85 degrees C.) or above by the time they are sufficiently tender.

For sanitary reasons, every portion of a cut of pork must reach at least 140 degrees F. (60 degrees C.), and, to be certain that this is the case as well as for reasons of palatability, the well-done stage is recommended. Veal, lamb, fish, and poultry are preferred well-done by most people, but tender cuts of beef are juicier when cooked only to the less-done stages. It should be remembered that tenderness is not entirely a matter of cut, however. The age and condition of an animal may be such that a cut usually considered less tender may be prepared by a method generally recommended for a tender cut.

Cooking Meat by Dry Heat

Roasting Meat. In the roasting of meat, as indeed in the cooking of meat by any method, the temperature and the time of cooking become the most important factors in controlling the changes that take place. Directions for roasting are often given in minutes per pound. As mentioned previously, this is not a means of securing uniform results, because factors other than weight, to be discussed later, influence the rate of heat penetration. Insertion of a thermometer affords a more satisfactory method of determining the stage of doneness.

In general, beef roasts reach a rare-done stage in about 20 minutes per pound, a medium stage in about 25 minutes per pound, and a well-done stage in about 30 minutes per pound. Fresh pork which is roasted to about 185 degrees F. (85 degrees C.) may require 35 minutes or more, depending upon the shape of the cut and the amount of bone it contains.

Allowance must be made for the rise in internal temperature that takes place in an unskewered roast after it is removed from the oven, if it is not cut immediately. The amount of rise is variable, depending upon the oven temperature and the internal temperature of the roast when it is removed from the oven. One investigator found that, when beef roasts of an internal temperature of 124 degrees F. (51 degrees C.) were removed from an oven registering 257 degrees F. (125 degrees C.), they gained an average rise of 18 degrees F. (8 degrees C.) over a period of 40 to 45 minutes. (See Fig. 32.) Similar roasts removed from the oven when their internal temperature was 160 degrees F. (71 degrees C.) showed a rise of only 7 degrees F. (4 degrees C.).[29] Thus meat which is cooked to the rare stage when removed from the oven may be

[29] Latzke, *N. D. Agr. Expt. Sta. Bull.* 242 (1930).

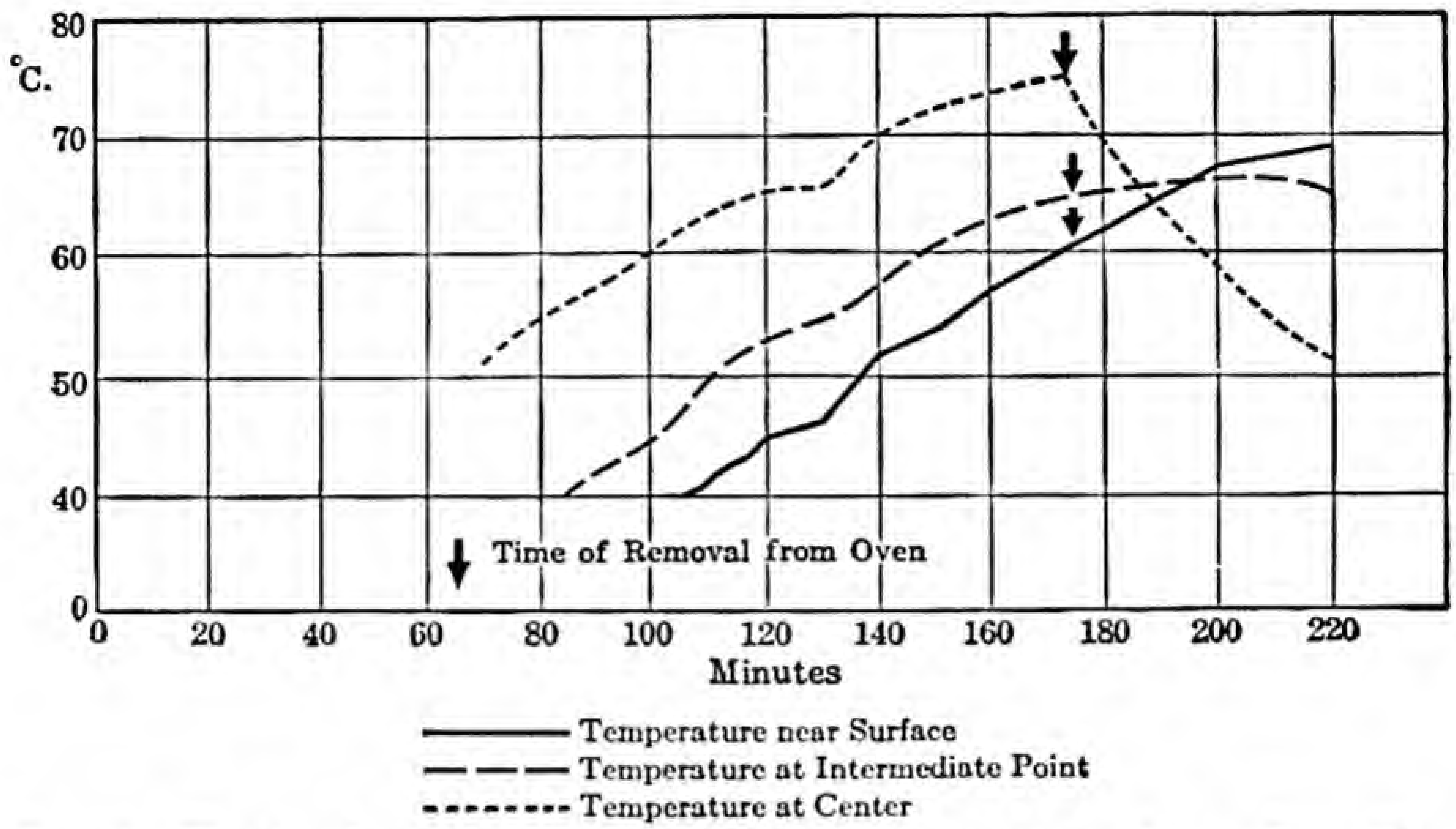


FIG. 32. The rise of temperature in a roast (oven temperature 125 degrees C.). (*From N. D. Agr. Expt. Sta. Bull.* 242.)

medium-done before it is cut. The higher the internal temperature on removal from the oven or the lower the oven temperature, the smaller the rise and vice versa.

Skewers, which are wires made of highly conductive metals, may be inserted into roasts to promote speed and evenness of cooking. (See Fig. 31.) If they are left in when the roast is removed from the oven, the internal temperature drops immediately.[30]

Factors affecting time required for roasting to a particular stage of doneness. The time required for producing a particular stage of doneness depends upon (1) the temperature of the oven, (2) the composition of the cut, (3) its size and shape, and (4) the presence or absence of skewers.

1. Naturally, the higher the oven temperature, the more rapid the heat penetration in a roast. At the BHNHE, paired beef roasts of the same weight (about 10 pounds) cooked to the rare stage [140 degrees F. (60 degrees C.)] required 25.4 minutes per pound in a constant low-temperature oven [257 degrees F. (125 degrees C.)] and 17.8 minutes per pound in a constant moderate-temperature oven [347 degrees F. (175 degrees C.)]. When cooked to the medium-done stage [158 degrees F. (70 degrees C.)] the time was 34.1 and 22.0 minutes per pound, and to a well-done stage [176

[30] Morgan and Nelson, *J. Home Econ.*, 18: 371 (1926).

degrees F. (80 degrees C.)] 47.7 and 27.2 minutes per pound, respectively.[31] The choice of a cooking temperature, however, is limited by the effect of high temperatures in dehydrating and toughening the fiber proteins. In the BHNHE experiments, losses were always greater in the moderate oven as compared with the low-temperature oven, though the difference was insignificant in the case of the well-done products. Recommended roasting temperatures are largely a compromise between the common desire for speed in cooking, which calls for high temperatures, and standards of palatability and economy, which call for low cooking temperatures to diminish losses, promote uniformity of doneness, and lessen shrinkage in servings. Lower oven temperatures have other advantages, such as giving an oven and utensils that are easier to clean, requiring less fuel, and producing less heat in the kitchen.

2. The relative proportions of bone, fat, lean, and connective tissue affect the rate of penetration of heat into a roast because of their differences in conductivity. Boneless roasts require more time per pound than those containing bone. In general, fat in the solid state is a poor conductor of heat but in the liquid state it becomes a good conductor. Meat which has ripened requires less time to reach a particular stage of doneness.

3. Usually, other factors being similar, the heavier the roast, the less the time per pound required to cook it. It has already been mentioned that rolled rib roasts require more time per pound than standing rib roasts. This is doubtless due in part to difference in surface as well as composition.

4. The high conductivity of skewers hastens cooking. The increase in rate depends directly upon the amount of metal present. Thus in one test it was found that, when similar roasts were prepared with and without skewers, those without skewers required 20.2 minutes per pound, those with 179 grams of metal in skewers required 14.3 minutes per pound, and those with 264 grams of metal required 9.8 minutes per pound.* The time for cooking a pork roast was found to be decreased from 3 to 5 minutes per pound by using these devices, with a consequent saving of time and fuel.[32] However, because the cooking time is shorter, skewers tend to result in slightly less tender roasts.

[31] Alexander and Clark, *U. S. Dept. Agr., Tech. Bull.* 676 (1939).

* Morgan and Nelson, *op. cit.*

[32] Child, *Minn. Agr. Expt. Sta. Bull.* 254 (1929).

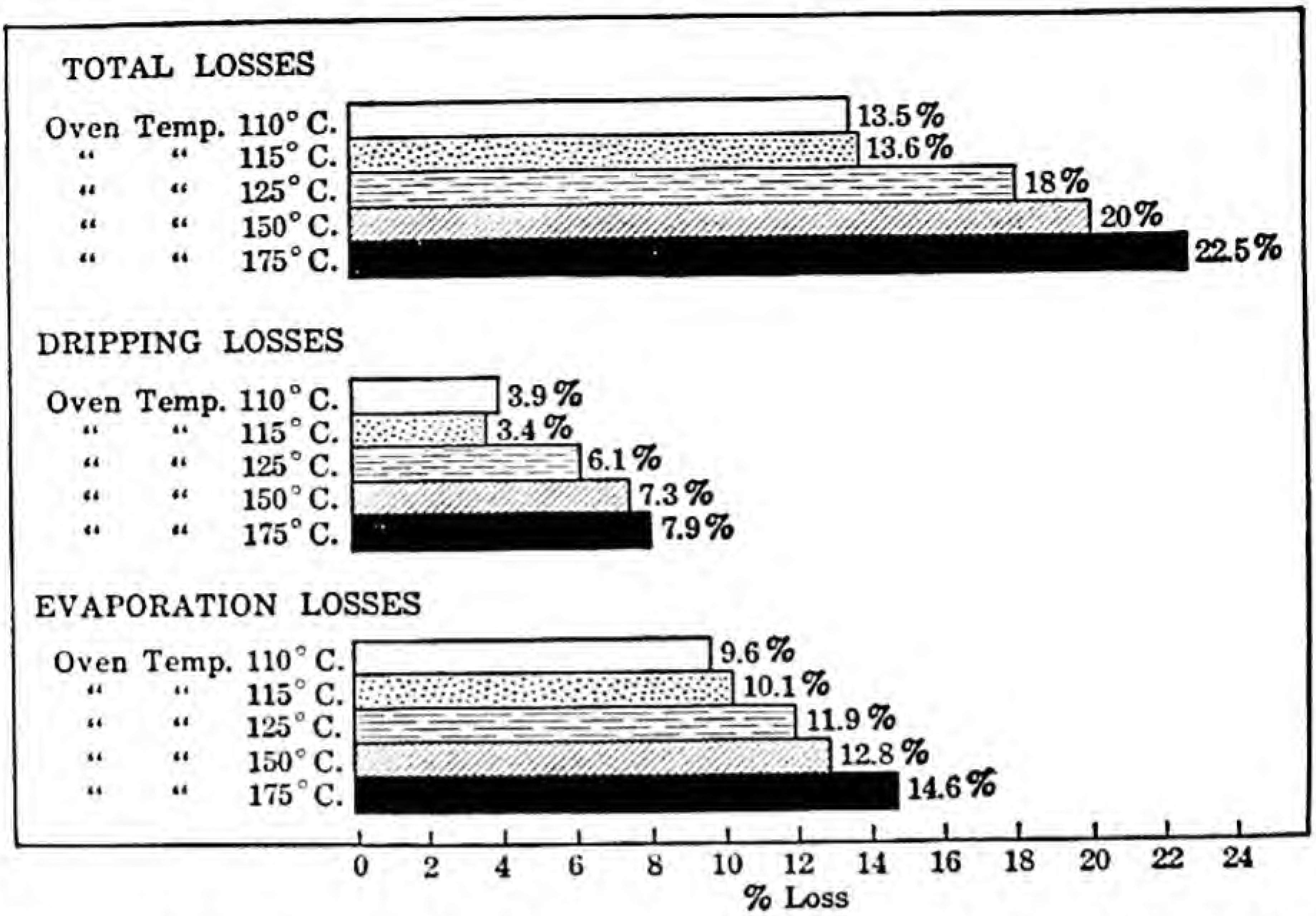


FIG. 33. Average losses in medium-done beef roasts cooked at various temperatures. (*From N. D. Agr. Expt. Sta. Bull.* 242.)

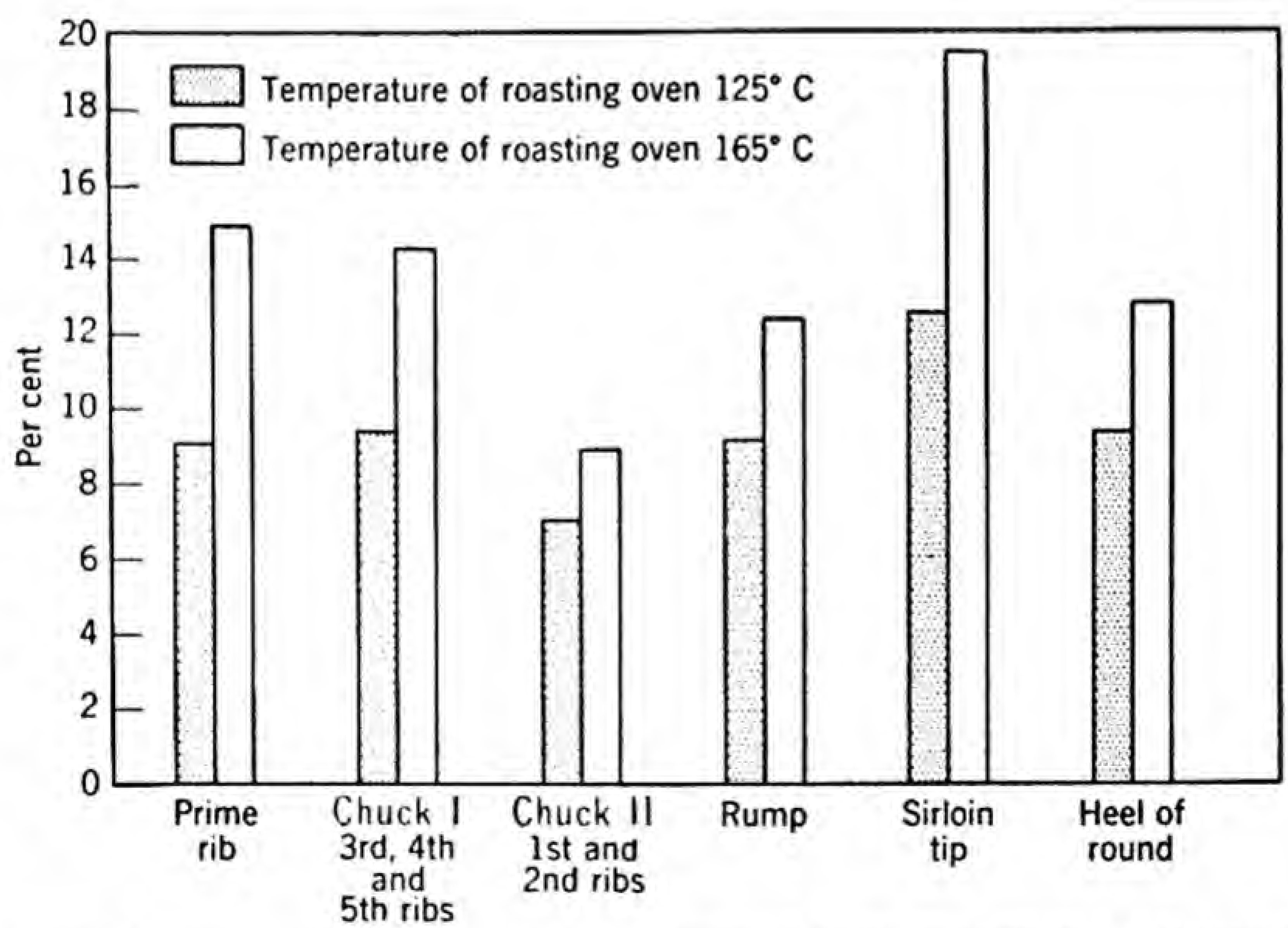


FIG. 34. Percentage cooking losses in various types of roasts in ovens at 125 degrees C. and 165 degrees C. (*From Mo. Agr. Expt. Sta. Bull.* 293.)

Factors affecting losses in roasting meat. The losses in roasting meat are of two types: losses by volatilization and losses to drippings or to the gravy. Neither is important from the standpoint of nutritive quality. Losses by volatilization consist largely of evaporated water. Losses to the drippings include water, melted fat, and a fraction of the minerals and water-soluble vitamins, but these are usually conserved and eaten with the meat. Juiciness and flavor of the meat itself are superior when losses, even to the drippings, are low. Furthermore, the smaller the losses, the more servings provided by the roast.

The amount of the shrinkage in roasting is influenced by (1) oven temperature, (2) stage of doneness, and (3) composition of the cut.

1. In some of the earliest experimental work on meat, it was discovered that high oven temperatures increased the losses in roasting meat. According to one study, roasts cooked to the medium-done stage lost 13.5 per cent when the oven temperature was 230 degrees F. (110 degrees C.), 13.6 per cent at 239 degrees F. (115 degrees C.), 18.0 per cent at 257 degrees F. (125 degrees C.), 20 per cent at 302 degrees F. (150 degrees C.), and 22.5 per cent at 347 degrees F. (175 degrees C.). (See Figs. 33, 34.) Figures 33 and 34 show the relationship of cooking temperatures and degree of doneness (length of cooking period) to losses in rib roasts of beef in other experiments.

2. Many investigators have found that the stage to which the meat is cooked has a marked effect on the amount of shrinkage. Meat cooked only to the rare stage loses less than that which is medium or well-done. (See Figs. 35 and 36.) In fact, the stage to which the meat is cooked is more important than the ordinary range of oven temperatures in its effect on shrinkage. In the BHNHE study referred to earlier, when eight-rib rolled roasts of beef were cooked to the well-done stage, there was very little difference in the amount of shrinkage in the low and moderate temperature ovens (27.0 per cent as compared with 28.3 per cent), but, when cooked to the rare stage, they shrank 9.3 per cent in the low-temperature oven [257 degrees F. (125 degrees C.)] and 16.4 per cent in the moderate-temperature oven [347 degrees F. (175 degrees C.)]. Since skewers diminish roasting losses by shortening cooking time, pork roasts, which were skewered, lost only 8.89 per cent of their weight, whereas similarly cooked unskewered roasts

lost 12.28 per cent of their weight and required 6 minutes per pound longer for cooking.

3. Fat and water are the constituents contributing to losses in cooking that vary most in quantity in the meat. Well-fattened, high-grade beef ribs shrink more by drippings but less by evaporation than lean, low-grade ribs.[33] Total losses do not vary so greatly with composition differences as losses by either drippings or evaporation.

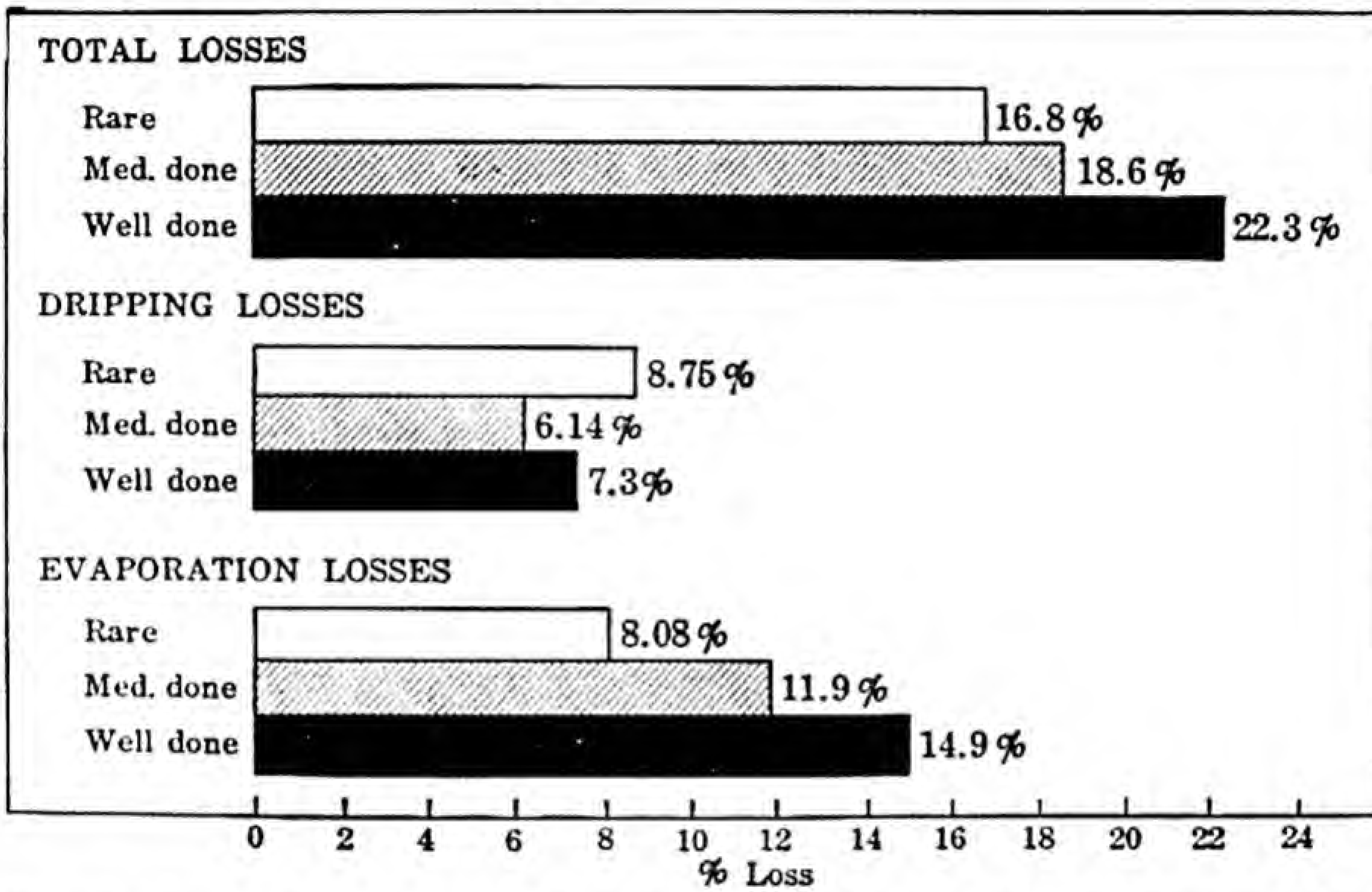


FIG. 35. Average losses in rare, medium-done, and well-done beef roasts, oven temperature 125 degrees C. (*From N. D. Agr. Expt. Sta. Bull.* 242.)

Rolled rib roasts shrink more than standing rib roasts cooked under similar conditions.[34] This is probably a result of the extra time required for cooking the former rather than any factor of difference in composition.

Practical recommendations for roasting meat. Cooking to the rare stage only increases juiciness and flavor, and results in a larger number of servings than cooking to more-done stages. Beef and fish are especially suited to cooking to the rare stage. The stage of doneness can be followed most accurately by observing a thermometer, the bulb of which is located in a piece of muscle (not in fat or touching bone) at the place most distant from all surfaces. If

[33] Alexander and Clark, *U. S. Dept. Agr., Tech. Bull.* 440 (1934). Also Alexander, *J. Home Econ.*, 22: 915 (1930).

[34] Alexander and Clark, *U. S. Dept. Agr., Tech. Bull.* 676 (1939). Also Child, *Minn. Agr. Expt. Sta. Bull.* 254 (1929).

the meat is not to be carved promptly upon removal from the oven, allowance must be made for a further rise in temperature.

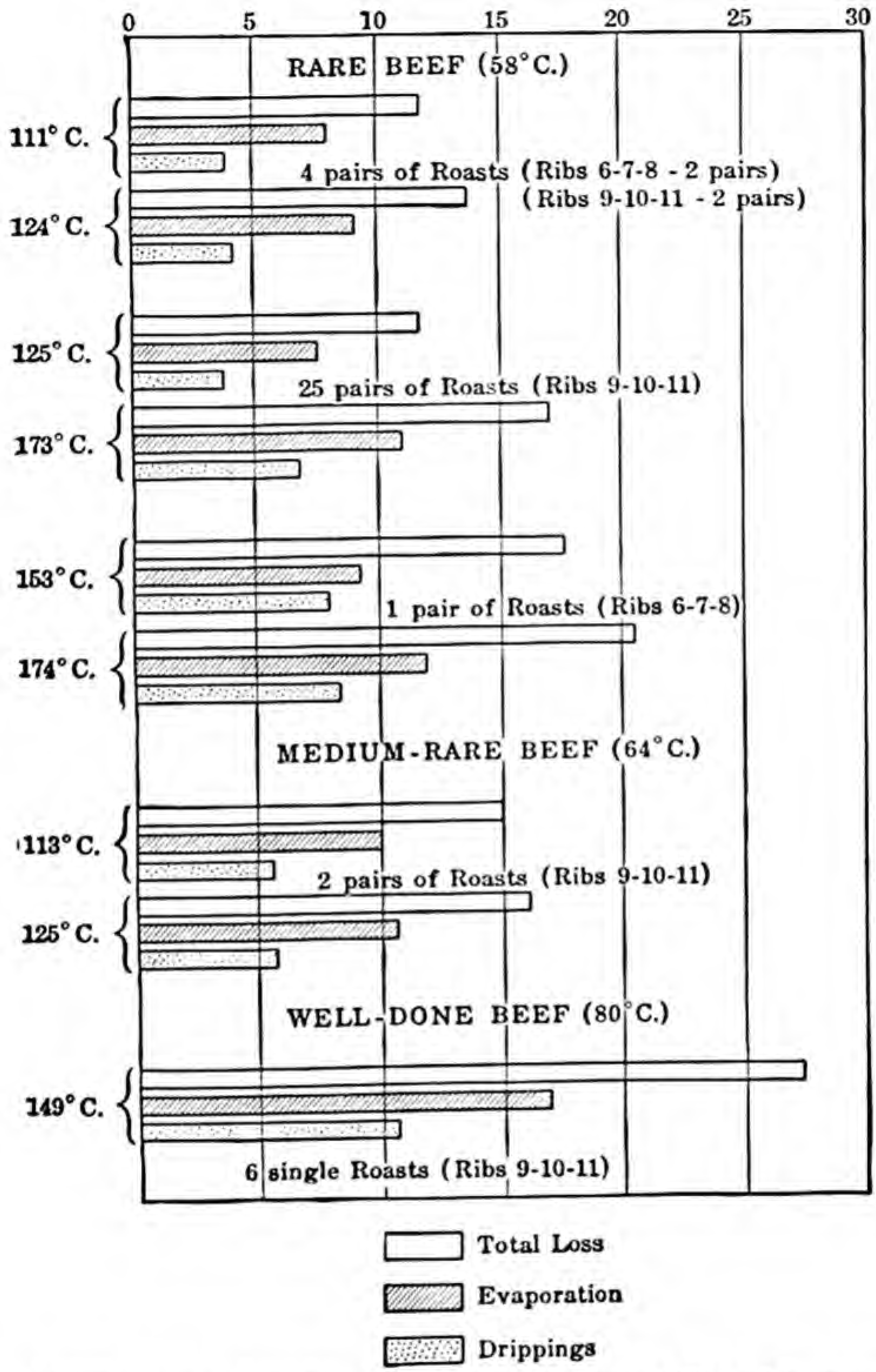


FIG. 36 . Shrinkage, or cooking losses, of rib roasts of beef. Effect of oven temperature and degree of doneness of the meat on total, evaporation, and drippings losses, expressed as per cent of the weight of the uncooked roasts. (*From Alexander.*)

Employing a high oven temperature (searing) at any point in roasting never decreases losses and, unless carefully limited, will increase shrinkage as compared with lower constant-temperature

cooking. Searing is unnecessary to brown the surface adequately in most cases. Because it is easier to control, uses less fuel, and results in greater uniformity of doneness, a constant-temperature method is preferable.

Within limits, the lower the oven temperature, the less the cooking losses will be. Also within limits, the lower the oven temperature, the greater is the degree of tenderness reached in the cooked meat. The principal disadvantage of extremely low oven temperatures is the time required. For beef roasts, 300 degrees F. (149 degrees C.) is satisfactory, except that 350 degrees may give preferable browning of small roasts. Small roasts of fresh pork and lamb may also be cooked at 350 degrees F. (177 degrees C.) to shorten the time required and facilitate browning but ham, veal, and lamb are better when roasted at the lower temperature of 300 degrees F. (149 degrees C.); 325 to 350 degrees F. (163 to 177 degrees C.) is recommended for chicken and duck; and 325 degrees F. (163 degrees C.) for goose and small turkey (6 to 9 pounds), with lower temperatures for larger birds. Whole fish should be baked at about 325 degrees F. (163 degrees C.), but split fish or fillets may be planked at 350 degrees F. (177 degrees C.). Skewers decrease cooking time and shrinkage but may result in less tenderness. Employing a very low oven temperature [260 degrees F. (127 degrees C.)] to prolong the cooking time may be practiced to increase the tenderness of doubtful cuts or those of inferior grade.

There is no advantage in salting roasts until serving because salt placed on the surface of the uncut meat does not penetrate more than a very short distance. Basting, that is, moistening the surface of the roast with the drippings, is of value only to reduce surface drying somewhat. Placing the fat side up, or, if the cut lacks surface fat, placing a thin layer of fat on the top is more effective. Water should not be added to oven roasts, and using a cover makes the product a pot roast because it is then cooked by moist heat.

Cuts suitable for cooking by roasting are as tabulated.

Beef	Veal	Pork	Lamb
Rib	Leg	Ham	Leg
Tenderloin	Loin	Loin	Loin
Rump, Prime or Choice	Shoulder	Shoulder	Shoulder
Top round, Prime or Choice		Boston butt	Ribs
Blade chuck, Prime or Choice			

Broiling and Pan-broiling. Slices from tender cuts of meat or the relatively thin cuts from tender birds or fish may be cooked rapidly without adding moisture or fat by radiant heat from a broiler or in an uncovered pan or griddle. The time required depends upon the temperature employed, the size and shape of the piece, and the stage of doneness desired. The best guide in broiling steaks over an inch in thickness is a horizontally placed thermometer.

As in roasting, choice of procedures in broiling depends upon their effect on palatability (especially such qualities as brownness of the surface, juiciness, and uniformity of doneness), shrinkage, and the time required. Cuts for broiling are thinner and cook in less time than roasts; hence a higher cooking temperature is required to produce the desired amount of surface browning. This may be a short-time high temperature for searing, followed by a much lower temperature [about 350 degrees F. (177 degrees C.)] intermediate between the two but higher than that recommended for roasting beef. The latter method is more likely to give uniform results. The temperature at the meat surface can be regulated by changing the heat input, or in some ovens by changing the distance of the meat from the source of heat.

Pan or griddle broiling is especially suitable for thin chops or steaks. The temperature should not be allowed to get hot enough to produce sputtering or smoking. Added water or a cover should never be used because the method is then transformed to braising which gives different palatability qualities. Melted fat is also poured off as it accumulates to maintain true broiling.

In general, some form of broiling is a suitable method of cooking tender cuts of beef and lamb, or ground meat patties of either, ham, bacon, and sausage, but braising produces superior palatability in pork chops and veal.

Frying. Meat is fried when it is partly or completely immersed in hot fat during cooking; when the meat is completely immersed the method is called *deep-fat frying;* when a smaller amount of fat is added or allowed to accumulate, the method is called *frying, pan frying,* or *sautéing.* These methods are suited to very lean meats such as liver or cubed steak and to any tender meats or meat mixtures which are coated with flour, meal, or crumbs. The fat should be kept below the smoking point. Using a thermometer and temperatures of 350 degrees F. (177 degrees C.) for precooked meat or 300 degrees F. (149 degrees C.) for raw meat is usually satisfactory in deep-fat frying.

Cooking by Moist Heat

In cooking by moist heat the cooking medium may be steam or water.

Braising and Pressure Cooking. Meat may be cooked in steam with or without pressure. The steam may come entirely from the water in the meat itself or partly from liquids added in small amounts. Pork chops are more palatable if cooked without added liquid. When the meat is first browned in its own or a small amount of added fat and then covered to cook in steam without pressure, the method is known as braising. Meat braised in a large piece is called a pot roast; that braised in small pieces, a fricassee. Chops and steaks may be braised, especially pork and veal chops and less tender beefsteaks. Less tender steaks, like pot roasts, require long cooking to make them tender by changing the collagen. Veal is not tough but contains much collagen and is improved in both texture and flavor by this method of cooking. Braising is preferable to broiling for fresh pork steaks or chops because it produces less hardening and drying of the fibers when the meat is cooked to a safe stage of doneness.

The steaming phase of braising may be performed on the top of the stove or in the oven, in a casserole for instance. Braising has been less thoroughly investigated than roasting, but the general aim is to produce a well-browned product which is both tender and juicy. Because the cuts employed are usually those containing relatively large amounts of connective tissue, the time of cooking must be sufficient to allow for enough conversion to gelatin to produce tenderness. This means also that the meat will reach the well-done stage, and the muscle fibers will lose much of their juice. When meat is cooked too long by moist heat, the fibers separate and the piece is difficult to carve properly.

Pressure-saucepan cooking. Although the temperatures of the cooking medium when cooking meat under pressure are much higher than those of steaming, simmering, or boiling, the losses have been found to be about the same if the meat is cooked to the same stage of doneness. In a comparison of cooking heel-of-round in the oven (48.8 minutes per pound), on the top of the stove (47.8 minutes per pound), and in a pressure saucepan (15.4 minutes per pound), total losses varied only from 33 per cent for the oven-cooked to 36 per cent for the top of the stove products, with the

pressure saucepan giving an intermediate value.[35] When beef and lamb stews were pressure-cooked, boiled, and simmered [kept at 184 degrees F. to 203 degrees F. (90 to 95 degrees C.)] to the same stage of doneness, there was very little difference in loss of weight, which ranged from 41.4 to 42.6 per cent for browned beef stews, and 43.3 to 45.6 for browned lamb stews.[36]

Meat cooked in water imbibes a portion of the liquor if allowed to cool while standing in it. The amount regained varies with the cooling temperature. Data on weight changes for hams cooked in water and cooled in it at various temperatures are given in Table XLI.

Table XLI. Average losses in hams cooked in water and cooled at various temperatures

[After Child]

Cooling temperature, degrees C.	Per cent fat	Loss from ham broth	Total loss
21.1	4.53	4.44	8.97
7.2	3.28	3.50	6.78
4.4	1.61	0.97	2.58
1.6	2.00	−2.10	−0.11 (gain)
−1.1	3.60	1.23	4.83
−3.9	2.43	2.58	5.01
−6.6	3.61	2.80	6.41
−17.7	3.93	3.05	6.99

Maximum imbibition capacity was reached by cooling to 35 degrees F. (1.6 degrees C.).[37] Stewed chicken has been found to show the same tendency.[38]

The stage of doneness in large pieces of meat cooked in water may be observed by the use of a thermometer inserted in the same way as in a roast. Although the time required may be estimated on the basis of the weight of the piece, as in roasting it is affected by the cooking temperature, and the shape and composition of the meat as well. Special treatments of the meat may also be a factor in cooking time. Tenderized hams cooked in water are preferable when heated only to 160 degrees F. (71 degrees C.), because they are juicier and easier to slice, but other hams may be improved by being heated to 171 degrees F. (77 degrees C.).

[35] Tucker et al., *J. Am. Dietet. Assoc.*, 22: 877 (1946).

[36] Cover et al., *J. Am. Dietet. Assoc.*, 23: 501 (1947).

[37] Child, *Minn. Agr. Expt. Sta. Bull.* 254 (1929).

[38] Alexander and Schopmeyer, *Food Technol.*, 3: 263 (1949).

Stewing or Simmering. Meat may be cooked by immersing it in water. To minimize the hardening effect of high temperatures, simmering is preferable to boiling. Small pieces of meat cooked by simmering are called stews. Meat for stewing may or may not be browned before the liquid is added. Vegetables are often added to stews to enhance their flavor. Cured meats such as ham and corned beef are especially suited to simmering because they have pronounced flavor.

Many people believe that meat which is plunged into boiling water at the beginning of stewing loses less to the broth than when started in cold water, because it is assumed that the outer proteins coagulate and prevent the escape of juice. Actual tests, however, show that there is practically no difference in the shrinkage produced by the two methods. Furthermore, browning meat before stewing actually slightly increases total weight losses as compared with the unbrowned product.* The amount of water also makes very little difference in relation to shrinkage.

In general, shrinkage of meat cooked by moist heat methods is greater than that in meat cooked by dry heat methods. This is partly a result of the necessity of reaching a more advanced stage of doneness to dissolve the connective tissue in the types of cuts for which moist heat is usually employed. Putting a cover on an oven roast has been found to increase the total weight loss.

The Appraisal of Cooked Meat

Nutritive Quality

Cooked meat always undergoes the two types of losses—those by solution and those by inactivation. However, because the pan juices or broths are so tasty they are seldom discarded. Part of the fat may be removed but the remainder which contains dissolved minerals and vitamins is ordinarily consumed as gravy or soup.

Tests on a large variety of flesh foods show that thiamine is the only major B complex vitamin subject to substantial loss by inactivation in cooking. In most cases, somewhat more than half of it is retained if the juices are consumed. Losses of riboflavin and niacin by inactivation are usually negligible, but both are readily soluble in cooking liquids and juices. Since the proportion of thiamine inactivated is related to the time of heating, roasting to the well-done

* Cover et al., *op. cit.*

stage causes somewhat greater losses than roasting to the rare stage. Roasting in general produces greater inactivation than broiling or frying.* There appears to be but little additional inactivation of thiamine during holding of meat after cooking.

Contrary to a common popular opinion, associated perhaps with the old-fashioned type of hospital diet which was basically one of broths and gruels, meat broth has no remarkable nutritive value. In fact, its nutritional contributions are limited to small amounts of minerals and of the vitamin B complex. Broth contains a large proportion of the flavorful extractives of the meat and is primarily an appetizer.

Digestibility

Both the fat and the protein of cooked meat are almost completely absorbed. The time meat remains in the stomach is probably dependent upon the proportion of fat, size of pieces swallowed, and amount of cooking. The more fat, the larger the size of pieces swallowed, and the greater the drying and crusting during cooking, the longer will be the time. Thus pork, because it contains more fat among the muscle fibers, remains in the stomach longer than beef.

A range of 2 to 4 hours covers the time that a variety of meats prepared in different ways remain in both slow- and rapid-emptying types of stomachs.[39] Meat is only partly digested in the stomach, intestinal and pancreatic enzymes completing the process. In general, there is no evidence of important differences between kinds and cuts of meat in completeness of digestion of their protein. All kinds and cuts of meat are relatively completely digested, whatever the method of cooking.

Sanitary Quality

Although cooking flesh foods improves their sanitary quality by killing pathogenic organisms, these products remain highly perishable and readily subject to new contamination. They should be cooled to refrigerator temperatures promptly when the meal is over. Contrary to a popular belief, all types of meat or meat gravies and soups may be placed in covered containers in the refrigerator while they are hot, although this increases the cost of cooling. In any

* For literature on effects of cooking on the nutritive quality of meats, see list of references at the end of the chapter.

[39] Fishback et al., *Am. J. Physiol.*, 49: 174 (1919).

case the period of standing in a warm room should be limited. Ready-to-eat cold meats constitute the source of infection in a substantial proportion of *Staphylococcic* food poisonings. They should be held under refrigeration both at the store and in the household.

Palatability

In general, dry heat cookery of meat produces the changes in flavor and appearance which are preferred by most people. These can be in part obtained with products cooked by moist heat by preliminary searing. Relatively low cooking temperatures under most conditions cause least shrinkage and hence leave the juiciest, most flavorful meat. The stage of doneness is also important in relation to these properties—rare-done meat having more juice and internal flavor than well-done. Tougher cuts can be cooked by dry heat methods if the connective tissue is mechanically subdivided by grinding, cubing, etc. When cooked by moist heat they should not reach the stage where the bundles of fibers fall apart and make carving in thin slices impossible.

Economy

Cooking affects economy of meat in two ways: (1) the cost of the fuel required and (2) the amount of shrinkage in relation to number of servings of a given size. Since shrinkage does not necessarily involve a corresponding decrease in food value, it is of more significance in relation to commercial food service than in the home. In one study of the effect of different cooking temperatures on a pair of uniform beef rib roasts roasted to an internal temperature of 135 degrees F. (57 degrees C.), that cooked in an oven at 285 degrees F. (140.5 degrees C.) yielded sixty-two 66-gram slices as compared with fifty-one for the other cooked in an oven at 450 degrees F. (232 degrees C.).[40]

FROZEN MEATS AND THEIR APPRAISAL

Meat will keep for years if it is frozen and held in that state. With modern methods of "quick-freezing," beef will retain satisfactory palatability for about a year if properly wrapped and held at temperatures no higher than 0 degree F. (−18 degrees C.). Less time is better for other meats; fresh pork changes the most and is

[40] Vail and O'Neil, *J. Am. Dietet. Assoc.*, 13: 34 (1937).

preferable when held not more than 6 months. This form of processing is in very common use for fish and such meats as poultry, pork, and beef. (See Chapter 7 for processes used in freezing.)

Frozen meat may be thawed as the first stage of cooking, or more slowly at refrigerator or room temperatures. If thawing is part of the cooking period, the extra time required for doneness is hard to estimate. Prethawing in a refrigerator is preferable to thawing at room temperature from the standpoint of sanitary safety. Steaks, chops, and cuts of similar size thaw in about 12 hours in a refrigerator, but large roasts or whole birds may require 24 hours or more.

Although freezing has not been found to have any significant effect on nutritive quality of meat, the evidence accumulating on the effects of holding in frozen storage indicates that thiamine and riboflavin may in some cases suffer substantial reduction. In one study, pork chops were found to lose about 40 per cent of the original thiamine and 31 per cent of the original riboflavin in 6 months, whether stored at −15 degrees F. (−26 degrees C.) or at 0 degree F. (−18 degrees C.). There were no losses of niacin.[41] In the case of beef, steaks from one animal lost but little if any of the B complex during 10 months at 0 degree F. (−18 degrees C.), but those from a different animal lost more than half of their riboflavin.[42] More research is needed to clarify the practical implications of these findings.

The drip from thawed meat contains considerable amounts of the B complex vitamins and probably also of iron, and should be conserved by adding it to the gravy. In beef, from 10 to 15 per cent of the thiamine, riboflavin, and niacin were in the drip.[43]

Freezing has not been shown to alter the digestibility of flesh foods.

Storage at quick freezing temperatures kills *Trichinellae* in pork; federal meat inspection laws specify the time and temperature approved to fit the dimensions of the piece of meat, 30 days at 5 degrees F. (−15 degrees C.) for large pieces, for example. The number of bacteria in meat diminish during holding in the frozen state, but increase rapidly after thawing. Precooked frozen foods containing meat, such as chicken à la king, should be quickly frozen

[41] Lehrer et al., *Food Res.*, 16: 485 (1951).

[42] Lee et al., *Food Res.*, 15: 8 (1950).

[43] Pearson et al., *Food Res.*, 16: 85 (1951).

and held in the frozen condition until thawed for immediate use.[44]

Freezing of meats, poultry, and fish far surpasses all other methods of preserving them in retention of their fresh eating qualities. The principal problems of deterioration in palatability are dehydration resulting in "freezer-burn" and rancidity development in the fat. Freezer-burn can be prevented by use of appropriate wrapping materials. Fat rancidity is a particular problem with pork and fish, and limits their storage life. Antioxidants such as ascorbic acid and monosodium glutamate are being found helpful in retarding this change in fish, pork, and other meats.[45]

So far as tenderness is concerned, most meats and poultry are improved by freezing. This results from the rupturing of the connective tissue caused by the ice crystals and from the enzyme activities which continue in frozen storage though at a slow rate. Freezing and frozen storage may raise the grade of meat, but it cannot be counted on to make tough cuts tender. Restricting ripening time before freezing, protecting from air, and holding at least as low as 15 degrees F. (-9.4 degrees C.) all aid in preserving palatability of frozen meat.[46]

Costs of quick frozen meats include not only freezing but special packaging and holding under refrigeration until they are used. Some economies in commercial frozen products result from cutting under factory conditions so that waste fractions, such as fat, bones, and trimmings, not only do not enter into shipping costs but may be more efficiently converted into by-products. As a rule, only products of the higher grades are quick-frozen and their retail prices approximate those of their fresh counterparts in grade and edible portion. When individual frozen lockers are available they are extensively used for holding meats which have been home-raised or purchased at wholesale. Substantial savings result from this method of eliminating most of the ordinary distribution charges.

CURED MEATS AND THEIR APPRAISAL

Curing or "corning" is a form of processing meat in which certain substances are added to it to diminish perishability and improve

[44] Proctor and Phillips, *Am. J. Public Health*, 38: 44 (1948).

[45] Bauernfeind et al., *Food Technol.*, 5: 254 (1951). Norton et al., *Food Technol.*, 6: 405 (1952).

[46] Hiner et al., *Food Technol.*, 5: 223 (1951).

palatability. The ingredients of curing mixtures do not act as completely effective preservatives in the concentrations used for curing. They are harmless in the proportions employed. One ingredient of all cures is salt. To this may be added saltpeter (KNO_3), Chile saltpeter ($NaNO_3$), or sodium nitrite, sugar, and spices.

The ingredients of cures are chosen for their preservative values and for certain other effects. Salt restricts the growth of bacteria and, in sufficiently concentrated solutions, inhibits it altogether. The proportion employed in curing mixtures inhibits the development of putrefactive types and of those which help produce undesirable color. It also hardens muscle fibers, decreasing their imbibition capacity. Sugar gives flavor and helps produce favorable conditions for color development, but all these effects are negligible in long curing of hams and it may be omitted.[47] The function of the nitrite or nitrate is partially to act as an antiseptic. Nitrites, whether added as such or formed from nitrates by bacteria, produce nitrous acid which unites with the myoglobin to produce nitric oxide myoglobin or nitric oxide hemoglobin. During cooking, nitric oxide myoglobin is converted to nitric oxide myochromegen, which retains a reddish color. This color is familiar in cured ham, bacon, corned beef, and dried beef. Spices in the amounts in which they are now used are added principally for their effect on flavor, but, before other methods of preservation of meat were developed, they were employed in such large quantities that they had a preservative value.

The two methods of applying cures are (1) dry curing, in which the ingredients are rubbed on the surface of the meat at intervals; and (2) brine curing, in which the ingredients are made into a solution in which the meat is "pickled." In large pieces of meat such as hams, the penetration of the pickling solution is hastened by pumping it through the vascular system of the tissue. Vascular pumping makes it possible to use a smaller proportion of salt in the curing solution and to shorten the time for curing hams to a few days. Ground meat for frankfurters, bologna, and some other products is cured by mixing it directly with the curing ingredients. Both dry and brine curing have about the same action.

Most cured meat products are also treated by smoking and will be appraised in connection with the discussion of the process. Corned beef is a good example of an unsmoked cured meat. It has been

[47] Brady et al., *Food Res.*, 14: 303 (1949).

found to retain only 20 to 50 per cent of its thiamine, but 90 to 100 per cent of its riboflavin. When the corned meat was cooked, the thiamine in the meat was reduced to 8 to 21 per cent of the original and the riboflavin to 45 to 73 per cent. The leaching effects of the wet process are particularly detrimental to thiamine retention. Ready-to-eat meats of the sausage type in which the curing ingredients are mixed directly with the ground meat retain a high proportion of the original content of B complex. Bologna, liver sausages, minced ham, meat loaves, salami, etc., undergo no significant losses of riboflavin and niacin and not more than 26 per cent loss of thiamine in manufacture to the ready-to-eat stage. During additional cooking by either broiling or boiling, losses of thiamine in frankfurters have been found to be less than 15 per cent.[48] Frankfurters, liver sausages, and minced ham are smoked as well as cured.

No particular changes in digestibility of cured products have been reported. The major effects, aside from reduction in thiamine value, are some increase in keeping quality and characteristic changes in flavor and color. The concentration of nitrite or nitrate is so small it is believed to have no physiological action.

SMOKED MEATS AND THEIR APPRAISAL

Smoking is one of the oldest methods of preserving meats. Today it is used primarily for improving keeping quality and palatability of fish and pork. Dried beef and some turkey and other poultry are also smoked. Fish is especially perishable, both on account of its tendency to self-digestion (autolysis due to enzyme action) and its being a good medium for the development of microorganisms. Flesh which is to be smoked is usually soaked in a strong brine, or in a curing solution, before it is exposed to the smoke.

Smoking exerts its effects through (1) surface drying and (2) permeation of the flesh with creosotes. Surface drying is usually sufficient to form a pellicle or skin. The formation of this skin is considered particularly important in the preservation of fish because it greatly increases resistance to bacterial action. Since creosotes do not readily penetrate flesh, the thinner the pieces smoked, the more effective is the preservative action. Such lightly smoked fish as finnan haddie remains extremely perishable.

[48] Beuk et al., *Food Res.*, 15: 303 (1950).

The principal change resulting from curing and smoking meats is a loss of thiamine which in hams amounts to 15 to 25 per cent, depending upon the methods used. This loss takes place largely in the curing phase. Smaller losses of other water-soluble constituents take place. During holding of ham, for example, a small additional loss of thiamine develops but niacin and riboflavin are more stable.[49]

Smoking has not been reported to affect digestibility of flesh foods and their wholesomeness is seldom questioned. It has been pointed out that creosotes and other compounds in smoke are poisonous and, although only small amounts are present in smoked foods, perhaps moderation in their consumption is advisable. Lightly smoked and salted foods such as fish are not sterilized and remain highly perishable. They are also often eaten without cooking, and have been responsible for cases of food poisoning. For them to be safe, sanitation and refrigeration must be adequate from the factory to the table of the consumer.

The flavor of smoked meats is very characteristic and is caused by the volatile constituents of the smoke, which vary with the nature of the burning material. Hard woods are usually preferred. Certain constituents of the smoke also give the surface of the flesh a brownish color which is considered desirable. The heat stabilizes the red color of the nitric oxide myohemoglobin. Flesh which has been smoked increases in tensile strength; that is, greater force is required to break the fibers, a fact which greatly facilitates handling of fish. The variety of smoked flesh products is increased by varying the amount of smoking to which they are subjected. Thus we may obtain both mild-smoked fish and hard-smoked fish in many markets. Long aging of cured and smoked meats develops new flavors such as those characteristic of Southern ham. They are believed to be a result of partial hydrolysis of fats and proteins and are often described as pungent, cheesy, and spicy. "Tenderized" hams and picnic shoulders are retained in a hot smokehouse until the internal temperature reaches 142 degrees F. (61 degrees C.). They require further cooking for complete protection from *Trichinellae*. Hams labeled "ready-to-eat" are safe without further heating because they have been held in the smokehouse until the internal temperature reached 155 degrees F. (68 degrees C.).

[49] Schweigert et al., *J. Nutrition*, 26:73 (1943); 27:419 (1944). Also Hoaglund et al., *Food Technol.*, 1:540 (1947).

Various liquid preparations made from creosote by condensing the volatile constituents of wood smoke are on the market for use as labor-saving substitutes for smoking. They do not give a product equal in palatability to that exposed directly to smoke. A material known as "smoked salt" is reported to be satisfactory for certain sausages, but the U. S. Department of Agriculture has ruled that it is misleading in name and may not be used in the products of plants under government inspection. This restriction also applies to "liquid smokes."

Curing and smoking lengthen the storage life of fish and pork and are relatively economical methods of processing them. However, it should be remembered that, owing to the much smaller amount of salt now used in many of these products, they are much more perishable than formerly and should be refrigerated.

DRIED MEATS AND THEIR APPRAISAL

Primitive people preserved meat and fish by drying thin strips in the atmosphere to a point where the water content was so low that the growth of microorganisms was inhibited. Although other methods of preservation of flesh foods have largely supplanted drying because they give a more palatable product, or for other reasons, the method is still practiced. A good grade of dried beef contains 55 per cent of water as contrasted with approximately 73 per cent in the fresh meat. Artificial heat, giving temperatures of 120 to 130 degrees F. (49 to 54 degrees C.), and resulting in coagulation of some of the proteins, is now employed for the drying temperatures. A short pickling in brine and smoking are a part of the processing of dried beef and add to its keeping quality as well as to its palatability. During World War II there was considerable development of drying of fresh raw and cooked pork and beef for purposes of preservation and concentration to minimize shipping space. As was true of dehydrated vegetables, the palatability of these products was not sufficient to develop a peacetime market for them, and dried beef and certain types of dried fish remain the principal products of the type now available. The major change in nutritive quality produced by dehydration is a substantial loss of thiamine which progresses during storage also.[50] Dried meats are not sterile and are usually canned or heavily salted for long preservation.

[50] Rice and Robinson, *Food Res.*, 9: 92 (1944). Whitmore et al., *Food Res.*, 11: 419 (1946). Orent-Keiles et al., *Food Res.*, 11: 486 (1946).

CANNED MEATS AND THEIR APPRAISAL

Meats which are cooked to a medium stage have been subjected to a pasteurizing temperature, but, for effective preservation by heating alone, they must be sealed away from air and undergo higher temperatures. In commercial canning, steam-pressure temperatures of 230 to 250 degrees F. (110 to 121 degrees C.) are employed and result in complete or almost complete sterilization. Meats canned in this way will keep for an indefinite period. Shorter processing times or lower temperatures with incomplete sterilization are sometimes employed commercially for whole hams or other large cuts or whole birds. These products must be held under refrigeration. The less extended processing gives a product of higher palatability.

The principles involved in household canning of meat are those already set forth for canning nonacid vegetables, because the *Botulinum* organisms can develop in meat. Complete or almost complete sterilization is desirable. This requires processing in steam under pressure rather than in a water bath. (See Chapter 7.)

According to existing evidence, canned meat is similar to the same meat cooked to a well-done stage in nutritive quality, digestibility, and sanitary quality, except for a greater loss of thiamine in the canned product and an uncertain amount of damage to the biological value of the protein. Losses in thiamine during the period of pressure cooking required for home processing have been found to run as high as 80 to 85 per cent. Further losses of this vitamin develop during storage.[51] The significance of the heat in reducing the protein value of canned meat is difficult to appraise on the basis of existing evidence.

The substitution of freezing for household canning of these foods is obviously desirable from a nutritional standpoint. Commercial processing in family-size (12 ounce) cans is far less destructive of thiamine than processing in larger-size cans. Retentions of about 75 per cent are reported for the family-size cans.[52] This advantage of commercial processing is a result of the small size of container and the more carefully controlled conditions of heating. In view of the rapidly increasing consumption of these products, it is fortunate that no greater losses occur.

[51] Cover et al., *Food Res.*, 14: 104 (1949). Mayfield and Hedrick, *J. Am. Dietet. Assoc.*, 25: 1024 (1949). Millares and Fellers, *Food Res.*, 14: 131 (1949).

[52] Greenwood et al., *Ind. Eng. Chem.*, 36: 992 (1944). Reedman and Buckby, *Can. J. Res.*, 21: 261 (1943), Section D. Rice and Robinson, *Am. J. Pub. Health*, 34: 587 (1944).

Canning probably makes no significant change in the digestibility of fresh foods except that the biological value of the protein may change since the heat required for canning alters the rate of release of important amino acids.

Canned meats are relatively safe foods. The Food and Drug Administration fairly frequently condemns commercially canned sea foods, but the spoilage probably developed before the product was put into the can. If the *Botulinum* organism develops in these foods, the offensive odor is likely to make it inedible.

Canned meats of the sterilized type are overcooked and tend to fall apart. For this reason cuts and grades of lower quality are the ones usually canned—they will always be tenderized in the processing. Fish of high quality is often canned, however, because, aside from freezing, this is the best method of preserving it.

Home canning of meat is an economical method of preserving farm-butchered meats. The large-scale cooking involved saves labor. Commercially canned products may also be relatively economical when one considers the savings in waste, labor, and fuel. This is no doubt the reason why their consumption has risen so fast.

GELATIN

Gelatin has been mentioned as the product of hydrolysis of collagen in the connective tissue of meat during heating. Frequently sufficient gelatin appears in the broth to cause it to set when cooled. Commercial edible gelatin is a dried form prepared from cheap sources such as bones and tendons. Its principal use is in the commercial production of ice cream and confections, but smaller amounts are used in other food mixtures for the special qualities which it confers. It is available on the market in either plain or acidulated form and in mixes which include sugar, acid, flavoring, and coloring materials.

The Structure and Composition of Gelatin

Gelatin, as the dried product comes to the consumer, consists of 85 to 86 per cent protein, 1 to 2 per cent ash, and 13 to 14 per cent water.

The products of the hydrolysis of collagen vary in structural make-up to include the range of substances between hard gelatin

and glue, the differences between them being due to difference in degree of dispersion. Gelatin has great power of imbibition and swells rapidly in cold water. Warm water disperses the swollen product to form a colloidal sol. When the sol is cooled its viscosity increases, and a typical gel is formed. The transition from sol to gel takes place at a temperature, or over a range of temperatures, known as the setting point. Gels once formed will melt to sols only at temperatures several degrees above those of setting.

Vigorous agitation, as in whipping, breaks up the structure of a gelatin gel, or lowers the viscosity of a sol that has not yet set, but after a period of standing the gel re-forms or the viscosity of the sol increases to the stage where it was before being whipped. In either case, this takes less time than was required for the first setting or thickening.

Gelatin in Food Preparation

The functions of gelatin in food preparation may be classified as follows:

1. To form bases for desserts and salads.
2. To produce viscous sols which will whip to form foams and are used in marshmallows, for example.
3. To serve as a protective colloid in such emulsions as mayonnaise.
4. To interfere with crystal growth in frozen mixtures.

The most important properties of gelatin from the standpoint of its use in food preparation are its viscosity in the sol state and its jelly strength in the gel state. Viscosity is probably related to the swelling power of the colloidal particles of gelatin, whereas jelly strength is related to the length of the micelles and the amount of bonding. Both vary with the kind of gelatin, especially with the manufacturing process to which it has been subjected, the concentration in which it is used, the temperature and hydrogen-ion concentration of the solution, the effect of other ingredients, and the time allowed for thickening or setting. Usually relative viscosity in the sol state is paralleled by the degree of stiffness in the gel state, but this is not always true.

When temperature, time, and other ingredients are kept constant, the stiffness of a gelatin gel is controlled by the concentration of the particular gelatin used. From 1 to 2 per cent of gelatin will form stiff gels. Package labels give directions for the proportion of

liquid to be added, but this may be varied to adjust to other factors. For example, to speed up gel formation, to produce a firmer gel at a higher setting temperature, or to produce a gel which will remain stiffer at a warm serving temperature (a hot day for example), less liquid should be added. Other conditions which tend to reduce stiffness in gelatin gels and which may be offset by higher concentrations of gelatin are the addition of highly acid fruits, or fruit juices, the incorporation of many solid pieces of food which interfere with the formation of long micelles, and whipping, which forms a foam and increases volume.

Stiffness in gelatin gels increases for a period after the gel is first formed, and, the lower the temperature at which a gel is held, the stiffer it becomes. The increase in jelly strength caused by some ingredients occasionally added to gelatin, milk products for example, has been attributed to the influence of salts which they contain. Sugar in amounts ordinarily used has little effect on the jelly strength of gelatin. Raw pineapple contains a protein-digesting enzyme, *bromelin*, which interferes with gel formation by breaking down the gelatin molecules.

The Appraisal of Gelatin As a Food

In nutritive quality, gelatin is of very limited value. Practically its sole contribution is protein, and that is very small in amount per serving of jelly because it is so highly diluted with water. Furthermore, the protein in gelatin is incomplete, as it is lacking in the three essential amino acids, tryptophan, cystine, and tyrosine. One tablespoon of gelatin, which makes 1 pint of jelly, supplies only twenty-nine calories. It contains no appreciable amount of any vitamin.

Gelatin is quite rapidly and completely digested, but this does not attach to it any practical superiority over common food proteins. Claims that the addition of gelatin to milk improves its digestibility are not justified.[53] An advertising campaign, based on results of some inadequately controlled experiments, has attempted to establish fatigue-preventing value for gelatin attributed to its content of aminoacetic acid. Other experimenters have failed to find such an effect.[54]

[53] Ray et al., *Proc. Soc. Expt. Biol. Med.*, 40: 157 (1939).

[54] Hellebrandt et al., *Proc. Soc. Expt. Biol. Med.*, 43: 629 (1940); King et al., *J. Am. Med. Assoc.*, 118: 594 (1942); Maison, *J. Am. Med. Assoc.*, 115: 1439 (1940).

Gelatin is a very favorable medium for the growth of bacteria and is employed by bacteriologists for that purpose. Under the close supervision practiced in modern manufacture of the edible product, the gelatins that reach the market are said to be exceedingly low in bacterial count. Dry gelatin does not contain enough moisture to encourage the growth of microorganisms. However, after water is added it is highly perishable and should be carefully refrigerated until eaten.

In general the role of gelatin as a food is primarily to contribute palatability through its texture qualities. In gels, it should be firm but not tough. Its neutral flavor and color are uninteresting but may be supplemented. It is not an economical food as measured by its nutritive value.

SUMMARY OF POINTS TO CONSIDER IN SELECTING AND PREPARING MEATS

1. Meats in general are important sources of protein, iron, and vitamins of the B complex in the average American diet. Liver is, in addition, the most potent food source of vitamin A. Meats are high in satiety value, and their flavor makes them a palatable main dish in any meal. But for most nutrients they are relatively expensive foods and, in particular, should not displace recommended quantities of milk in the food budget.

2. The price of meat varies more with certain palatability qualities, especially adaptability to dry heat methods of cooking, than with nutritional contributions of the edible portion. This is also true of cost differences among species, cuts, and grades. In general, pork and fish, organs, less tender cuts, and lower quality grades give the highest nutritive values in proportion to their cost.

3. Meats are more subject to sanitary hazards than most foods. They may transmit diseases and parasites of the animal as well as other organisms or the toxins of organisms with which they are contaminated. Competent inspection of the animal before slaughter, the meat itself, and slaughterhouses, as indicated by a federal inspection stamp, should be demanded by consumers. In addition, fresh or cooked meats should be held under refrigeration at all times.

4. Modern quick freezing not only preserves the fresh palatability qualities of flesh foods for at least 6 months but may produce some

tenderization of less tender cuts. Changes in sanitary quality and nutritional value are also insignificant if the thawing drip is utilized to conserve the nutrients that it contains. Their economy on the market can be judged by comparison of prices with those of their fresh counterparts.

5. Curing and smoking add to the variety of flavors of meats and on account of their preservative action may reduce their cost. Curing results in some loss of water-soluble nutrients, particularly thiamine.

6. Canning is the most effective method of preserving meat and also serves to tenderize tough cuts or the flesh of low-grade animals. Losses of thiamine are very high in household processing but little more than in ordinary cooking in commercial products. Costs should be judged by comparison with that of the edible portion of the fresh counterpart, the time-saving advantage of the ready-to-eat canned product being taken into account.

7. In the cooking of meat the most important considerations are choice of a method (whether it is dry or moist heat) adapted to the cut and grade, and the use of a temperature which limits shrinkage. The palatability qualities produced by dry heat methods are generally preferred, but these methods will not adequately tenderize less tender cuts "in the piece." Cooking to the rare stage only (suitable for tender beef and fish) gives the juiciest products and reduces shrinkage. Using relatively low temperatures when cooking by any method is preferable for the same reason. There is little or no advantage by any criterion of appraisal in buying meats of high grade for moist heat cooking.

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CHAPTER 13

FATS AND OILS

Formerly, the animal fats, including butter from milk, lard from pork, tallow from beef and mutton, and the single vegetable oil, olive oil, comprised almost the entire list of such foods. Corn oil and cottonseed oil began to be used for culinary purposes at the close of the last century but in small amounts. By 1930, it could be said: "An increase of about ten pounds per capita in the consumption of vegetable oils is one of the most striking changes in food consumption that has taken place in the past thirty years." [1] Improved methods of separation from plant tissue and further processing to enhance palatability have greatly increased the variety of edible fats and oils in common use. The list now includes in addition to cottonseed and corn oils: soybean, sesame, sunflower, coconut, palm, and peanut oil. Cocoa butter, made from the cocoa bean, is the only solid vegetable fat occurring naturally which is used to any considerable extent for food. It is employed in chocolate coatings for candy making.

Consumption of the newer vegetable oils has not been entirely at the expense of such previously consumed fats as butter. At least

[1] Montgomery, *Food Inds.*, 2: 511 (1930).

half of the new products represents a per capita increase in the total amount of fats and oils eaten, an increase resulting in part from the custom of trimming meats much closer so that less fat is brought into the household in that form, and in part to the general rise in the standard of living which permits the use of more shortened and fried foods which people like. The trend in the consumption of fats and oils is indicated in Table XLII.

Table XLII. Approximate per capita consumption of fats and oils, 1918–1948

[From *U. S. Dept. Agr., Misc. Pub.* 591 (1949)]

	Pounds per capita			
Kind of fats and oils	1918	1928	1938	1948
Bacon and salt side	17.0	19.7	16.2	19.2
Butter	13.7	17.4	16.4	10.0
Lard	11.7	13.1	11.0	12.7
Margarine	3.3	2.6	2.9	6.1
Shortening	10.4	9.3	11.5	9.6
Other edible oils	(3.7)	4.7	6.8	7.0

THE STRUCTURE AND COMPOSITION OF FATS AND OILS

Pure fats and oils are composed of carbon, hydrogen, and oxygen. Structurally they are triglycerides which are formed by condensation of 1 molecule of glycerol with 3 of fatty acid. Physically, fats differ from oils in being solid at ordinary temperatures [64 to 77 degrees F. (18 to 25 degrees C.)]; chemically they differ in that the fatty acids of the fats are for the most part saturated with respect to hydrogen, or composed of longer carbon chains, or both. Melting points are also affected by the distribution of the various fatty acids among the molecules. When the same amount of longer saturated fatty acids is combined with others to make mixed triglycerides, they have lower melting points than when combined as simple triglycerides. Natural fats and oils are mixtures of triglycerides of different melting points. This is evident in a natural oil such as olive oil; when it is placed in a refrigerator, it develops a cloudy appearance and becomes partially solidified. In the manufacture of the purified salad oils it is now customary to chill them at the factory and remove the soldified portions, because some consumers think the change is a sign of spoilage and because mayonnaise

made with the unseparated oils tends to demulsify when held in a refrigerator. This process is called *winterization.*

Purified vegetable oils can be converted into solid fats by the process known as *hydrogenation.* Hydrogenation is the direct addition of hydrogen at the double bonds in unsaturated fatty acid chains by means of a catalyst. Hydrogenation may be used not only to convert oils to solid fats but also to increase the consistency of natural fats. The process may be interrupted when the desired degree of hardening has been reached.

The practice of *superglycerination* is widely used to improve the emulsifying properties of shortenings. This involves the addition of mono- and diglycerides to fats. Mono- and diglycerides differ from triglycerides in containing only 1 and 2 molecules of fatty acid per molecule, respectively, instead of 3. They are substances containing both fatty acids, which are attracted by fat, and free hydroxyl groups, which are attracted by water. This makes them extremely effective in promoting the dispersion of shortening in doughs, particularly those with a high content of sugar.

Deodorization of fats and oils is a steam distillation process which removes most of the free fatty acids and renders the products tasteless and odorless.

To the eye, a solid fat appears to be a more or less homogeneous solid. Under the microscope it is seen to consist of a suspension of very small crystals enmeshed in liquid oil. The crystals are so small that their attraction for each other is greater than the force of gravity. Hence they do not settle out. The pores between them are so small that there is little tendency for the liquid phase to seep to the surface. Substances of this structure do not flow or collapse of their own weight but require a definite amount of pressure to change their shape and produce movement. They are known as *plastics.* In connection with fats, the term "consistency" is used more or less synonymously with plasticity.

The consistency of fats varies with the proportion of crystals, their size, shape, and rigidity, and the viscosity of the liquid portion. Increased stiffness is produced by increased proportions of crystals, smaller size of crystals, and by more viscous liquid. Raising the temperature reduces stiffness by melting some of the crystals and by decreasing the viscosity of the liquid. Fats are plastics of the type in which consistency decreases as they are cut or "worked," a change attributed to reduction of the cohesive forces between the solid particles.

Oils and melted fats are homogeneous liquids which are not plastic but viscous. Their viscosity varies with temperature and is a factor in emulsification as in making salad dressings.

THE DETERIORATION OF FATS AND OILS

Fats and oils are subject to a very important type of deterioration known as *rancidity*. Rancidity appears to be caused by at least two entirely different kinds of change, *hydrolysis* and *oxidation*. Hydrolysis requires the presence of water and results in the liberation of free fatty acids and glycerol. Oxidation occurs at the unsaturated linkages, forming peroxides. It results in a breaking of the carbon chains with the formation of aldehydes, ketones, and acids of lower molecular weight, some of which have unpleasant flavors and odors when present in very small amounts. Oxidation requires the presence of oxygen and is accelerated by heat, light, especially that in the violet and ultraviolet wavelengths, moisture, acids including those freed from the fat by hydrolysis, lipoxidative enzymes, and traces of such metals as copper and iron. It can be retarded by storage in airtight, lightproof containers, or in bottles or wrappers of the colors which absorb the active light waves, for example, certain shades of green and brown. Many of the conditions promoting oxidative rancidity likewise stimulate hydrolysis.

Rancidity may develop in a food containing a high percentage of fat as well as in the more or less purified fats. It is an important cause of deterioration of whole-wheat flour and other whole-grain cereals in the summer. The development of rancidity is not necessarily closely related to the length of time that the fat or fat-rich food has been stored. After it begins to develop, however, the rate of increase becomes progressively greater. There is no way to reverse the change.

Fats are relatively stable and resistant to the development of oxidative rancidity when they are naturally saturated, when they are highly hydrogenated, and when they contain substances known as antioxidants. Antioxidants are present in all natural unrefined fats and oils, there being more in those from plant sources. In fact, manufactured vegetable oil products retain enough of these substances to be relatively resistant to rancidity. Antioxidants occur in many seeds, for example, oats and soybeans. When they are added as flours to shortened food mixtures, such as crackers, they delay the onset of rancidity markedly. This natural antioxidant appears

to be *tocopherol* (vitamin E), which is relatively plentiful in vegetable fats but scarce in animal fats. If an antioxidant flour is added to lard, not only is the development of rancidity in the lard retarded but also that of food mixtures in which the lard is incorporated. Other approved antioxidants are now added to some lards as will be discussed later.

Rancidity is objectionable because it produces disagreeable odors and flavors and, after a period, undesirable changes in color and consistency. Rancid fats render the foods with which they are combined unpalatable. Furthermore, the development of rancidity is accompanied by inactivation of vitamin A, if present. It may also have undesirable physiological effects.

THE MANUFACTURE OF FATS AND OILS FOR HOUSEHOLD USE

Fat pork and bacon are natural foods high in fat which are marketed without any of the concentrating or purifying processes which other foods of this group undergo. Churning, rendering, and pressing are methods of separation employed to concentrate the fat fraction of animal or plant products. In many cases the concentrated product is further treated to purify it or to change chemically the type of fat present.

Butter

Buttermaking is a process of fractionation of cream in which the fat is relatively completely separated from the rest of the milk solids and from most of the water by churning. The structural change is believed by some to consist of a reversal of the fat-in-skim-milk emulsion, which is cream, to a buttermilk-in-fat emulsion, which is butter. In any event, the original emulsion is broken during churning. The agitation causes the fat globules to clump and finally to coalesce. The presence of such emulsifying agents as proteins and phospholipids prevents coalescence of water droplets when butter is heated, and as a result it foams quietly rather than spurts and spatters. The composition and plasticity of the product depend upon a number of factors such as the fat content of the cream, size of the fat globules, acidity, temperature, viscosity, and amount of agitation.

Butter may be made from either sweet cream or sour cream. Sour cream churns more readily and produces butter which has the flavor desired by more people, but sweet-cream butter is gaining in popularity. The first step in preparation of cream for commercial buttermaking is usually pasteurization. This is followed by ripening, as the process of souring is called, unless sweet-cream butter is being made. The souring may take place naturally, or it may be controlled by the addition of cultured lactic acid bacteria. Churning, a form of mechanical agitation, breaks the fat-in-skim-milk emulsion and results in the formation of lumps of butter. These are washed and usually salted. Unsalted butter, often known as sweet butter, is available on the larger markets, but salted butter is preferred by most people. After being washed and salted, the lumps of butter are "worked" or pressed to give a solid mass of desired texture. Artificial coloring, consisting of a government-approved coal tar dye or a natural vegetable product such as *annatto*, may be added. The principal flavoring substance in butter is *diacetyl*, a compound formed by the souring bacteria.

In the United States, butter made in factories is called creamery butter and that produced on farms, dairy butter. Cream for dairy butter is generally allowed to sour spontaneously; that for creamery butter is cultured. The use of cultured cream, together with more standardized processing under factory conditions, results in greater uniformity of flavor and other characteristics in creamery butter.

According to a definition established by Congress, butter must contain at least 80 per cent milk fat. The remainder consists of about 16 per cent water, 2 to 2.5 per cent salt, and about 1 per cent casein.

United States grades for creamery butter are assigned according to scores based on flavor, aroma, and physical characteristics. Most market butter scores from 90 to 93, and grades correspond as tabulated.

Grade AA	93 score
Grade A	92 score
Grade B	90 score
Grade C	89 score

Grade labeling is voluntary and usually limited to grades A and AA. Much of the deterioration in flavor is caused by microorganisms which hydrolyze fats, releasing butyric acid which gives a "tallowy"

flavor, rather than true oxidative rancidity. Holding at cold storage temperatures effectively preserves salted butter for many months.

Renovated butter is made from butter which has been melted. The fat is then separated from the water and curd, clarified, aerated, and churned with fresh milk, skim milk, or cream. Only butter of low grade is subjected to this process.

Margarines

Margarines (oleomargarines) are made by churning some form of milk with oils and fats other than butterfat. Originally, oleo oil and oleostearin from beef were used, but now nearly all the fat entering into margarine manufacture in the United States is made from cottonseed and soybean oils. The fats are emulsified with cultured cream, milk, or skim milk, then chilled, separated from the liquid, washed, and salted so that they resemble butter except in color. Artificial diacetyl, one of the compounds responsible for the flavor of butter, is usually added to margarines. A small amount of lecithin, or certain monoglycerides or diglycerides, may be included to aid emulsification and improve the quality of the product for pan frying. Margarines sputter more than butter when heated because they are less perfectly emulsified. To reduce development of microorganisms when margarine is stored without refrigeration, a limited amount of benzoic acid or sodium benzoate may be used. Artificial coloring may be added directly to the product or be packed with it in the form of a pellet or powder to be mixed by the homemaker. Some states discriminate against the ready-colored product by special taxation or outright prohibition of sale. Vitamin A concentrate with or without vitamin D may be added, but the vitamin A value must be not less than 15,000 USP units per pound. As with butter, federal standards for margarines require a minimum of 80 per cent fat.

Margarine, like butter, does not often exhibit true oxidative rancidity, but it may develop off-flavors from other changes. Even when it contains a preservative, its storage life is greatly extended by low temperatures.

Lard

Lard is the rendered fat from hogs. It usually contains not more than 1 per cent of substances other than fatty acids and fat. Render-

ing is the process of separating the fat from the connective tissues, etc., which form the structure holding it in the body of the animal. The separation is made by melting the fat, either by heating kettles containing the body fat, or by admitting steam under pressure to tanks in which it has been placed.

The properties of lard depend upon (1) the feed of the hog, (2) the part of the body from which it comes, and (3) various manufacturing processes to which it may be subjected, including the method of rendering, deodorization, hydrogenation, plasticization, fortification with antioxidants, and superglycerination.[2]

1. *The feed of the hog.* Hogs fattened on peanuts, soybeans, or cottonseed meal have a much softer fat than those fattened on corn.

2. *The part of the body.* Leaf lard is rendered from the fat which lines the body cavity. It is harder and considered of better quality than that from back fat or other areas.

3. *Manufacturing processes.* Most of the market lard is wet-rendered in closed tanks under pressure. This is known as *prime steam lard.* Rapid cooling gives it a smooth texture. *Kettle-rendered lard* is rendered in a steam-jacketed kettle at temperatures of 230 to 260 degrees F. (110 to 126 degrees C.), conditions which give a mild flavor. It is made from leaf fat or from a mixture of leaf and back fats. Kettle-rendered lards may be slow-cooled and consequently have a grainy texture resulting from early solidification of the higher-melting fractions into hard grains which are distributed through the softer, lower-melting portion. *Dry-rendered lard* is a newer type produced by rendering in a closed container with reduced pressure to lessen the amount of oxidation during heating and to facilitate the evaporation of water. It often has a dark color and a cooked flavor which is preferred by some commercial users. Deodorization by washing the lard with steam removes free fatty acids and other substances affecting flavor to give a product known as *bland lard.*

To harden them and to create uniformity for a brand, softer lards may be mixed with leaf lard or hydrogenated lard, or be all-hydrogenated. Special-brand lards adapted by superglycerination to shortening sweet products like cakes are also on the market. They are also subjected to plasticization, a creaming process in which the lard is worked and whipped with air.

[2] Deatherage, *Food Inds.*, 21: 1749 (1949).

Lard is more subject to rancidity than vegetable shortening because it is deficient in natural antioxidants. Practices which increase its stability include hydrogenation, and mixing it with vegetable oils or hydrogenated vegetable fats or an approved antioxidant such as *gum guaiac, NDGA* (*nor*-dehydroguaiaretic acid), or *propyl gallate.* Citric acid is sometimes added because it increases the effectiveness of certain antioxidants.

Lard compounds are mixtures of lard with other animal or vegetable fats. These may be also standardized in consistency by hydrogenation and treated by other processes used with lard.

Vegetable Oils

In this country vegetable oils on the retail market include olive oil and the purified vegetable salad oils.

Olive oil has been a staple food for thousands of years but now it forms only a small fraction of the vegetable oils consumed. It was originally an unpurified oil obtained by simple pressing. A first pressing yields the highest grade of oil, known as virgin olive oil. This is followed by one or two additional pressings, yielding oil of lower grades. As a final stage, the press cake is extracted with a suitable solvent, the product of which is refined, bleached, deodorized, and sometimes blended with other oil to prepare the type known as pure olive oil. The popular brands of olive oil are blends of oils from different pressings.

Practically all the neutral vegetable oils sold on the retail market are salad oils rather than cooking oils, the difference being that salad oils will not solidify at refrigerator temperatures, whereas cooking oil may do so. The oils used in largest quantities are cottonseed, corn, soybean, sesame, and peanut. Cottonseed oil requires winterization, but corn, sesame, and soybean oils do not. Soybean oil is used in smaller amounts than cottonseed, corn, and sesame oils because it has a tendency to revert to a "beany" flavor. Efforts to remove this handicap are increasingly successful and in the future it may disappear. Peanut oil is difficult to winterize because it deposits fat crystals which do not filter readily, and hence it is not much used in salad oils. Processing of salad oils includes treatment with alkali, deodorization, and sometimes bleaching with fuller's earth to remove undesirable flavors and color. Salad oils contain natural antioxidants and are relatively resistant to rancidity.

Vegetable Shortenings

Vegetable shortenings have become strong competitors of lard on the retail market and have largely supplanted butter in this role. They are either made of blends of highly hydrogenated oils with some of the liquid oil, or all-hydrogenated. For institutional use two major types are manufactured, a hard type, which is adapted to frying and pastry making, and a softer type, which is superglycerinated for making cakes and other sweet goods. Those available on the retail market are mostly of the latter type because it is assumed that homemakers want a single general-purpose shortening particularly suited to cake making. These shortenings are also creamed at the factory to make them easier to incorporate into flour mixtures and to provide air which assists in leavening. Vegetable shortenings retain the natural antioxidant property of vegetable oils, are highly resistant to rancidity, and do not require refrigeration.

THE APPRAISAL OF FATS AND OILS AS FOOD

Nutritive Quality

Food fats are particularly valuable as concentrated forms of energy. In pure forms, they yield about 4000 calories per pound, which is more than twice the fuel value of equal quantities of carbohydrate or protein. Butter and margarine, being required by law to contain at least 80 per cent fat, have a calorie value of about 3250 per pound. One tablespoon of either yields about 100 calories, and 1 tablespoon of pure fat or oil about 125 calories. The low bulk of fats in relation to their energy value is significant because the human digestive system is not adapted to the quantities of carbohydrates and proteins which would be required to meet energy needs if they alone were eaten.

Some fats contain vitamins A, D, or both, as well as other fat-soluble kinds not discussed in this book. The contributions that they make as a class toward meeting vitamin A requirements is the most important. The BHNHE found that fats and oils furnished some 19 per cent of the calories, and about 8 per cent of the vitamin A consumed in 1948.[3] The presence of fat facilitates the absorption of fat-soluble vitamins, also.

[3] *U. S. Dept. Agr., Misc. Pub.* 691 (1949).

Although most animal fats contain at least small amounts of vitamin A, the only significant natural source among this group of foods is butter. Like milk, butter varies in vitamin A potency according to the feed of the cow. The U.S.D.A. has estimated average winter potency to be 11,160 IU per pound, with a corresponding average summer potency of 17,995.[4] An average value of 15,000 IU per pound for the whole year has been adopted.[5] This amounts to 460 IU per tablespoon or 9 per cent of the daily *Recommended Allowance* for a physically active man. On the basis of 64 pats to the pound, 1 pat of butter furnishes 1½ per cent of the *Recommended Allowance* of energy and 4½ per cent of the daily *Recommended Allowance* of vitamin A for a physically active man.

The vitamin D content of butter is small, varying from about 45 to 450 IU per pound (0.1 to 1.0 per gram). Summer values are the highest.

All margarines are insignificant sources of vitamin A unless they are reinforced with purified fish oils or other concentrates. Most brands are now fortified to the level of 15,000 IU per pound, which makes them the equivalent of average butter. In England, both vitamins A and D are added to margarines. In this country no efforts have been made to promote addition of vitamin D, and whether it is present or not depends primarily on the source of the vitamin A. Fish oil concentrates contain both, for example.

Many researchers have attempted to discover differences in the nutritive value of butter and margarines, but, aside from their relative content of vitamin A, without conclusive results. It has been pointed out that the fats of human milk and cow's milk differ greatly in composition and that a typical margarine fat actually resembles human milk fat more than butterfat does.[6] The Food and Nutrition Board of the National Research Council and many individual authorities have gone on record that, so far as existing evidence goes, fortified margarine may be used in place of butter in mixed diets with no measurable nutritional deficiencies.[7]

Aside from differences in vitamin value, fats differ in content of certain essential unsaturated fatty acids (linoleic, linolenic, and arachidonic), but such small amounts of these are required that

[4] Maynard et al., *U. S. Dept. Agr., Misc. Pub.* 571 (1945).

[5] Watt and Merrill, *U. S. Dept. Agr. Hdbk.* 8 (1950).

[6] Baldwin and Longenecker, *J. Biol. Chem.*, 154: 255 (1944).

[7] Deuel, *Science*, 103: 183 (1946).

neither natural differences nor the reduction suffered in hydrogenation probably has any practical significance.

Digestibility

The common food fats are relatively completely digested, 95 to 98 per cent being absorbed. Such differences as have been found in human digestion are related to melting points, the fats melting at temperatures above 122 degrees F. (50 degrees C.) being less completely absorbed, probably because they are less completely emulsified, and hence less completely hydrolyzed. Thus experiments have shown that about 88 per cent of mutton suet, with a melting point of 122 degrees F. (50 degrees C.), is digested and absorbed, whereas about 97 per cent of butter, which has a melting point of 90 degrees F. (32 degrees C.), and about 98 per cent of olive oil, which is fluid at room temperature, are absorbed. Commercial general-purpose shortenings are said to be hydrogenated to melting points of 105.8 to 109.4 degrees F. (41 to 43 degrees C.). Hence they are well within the range of high digestibility.[8] In an ordinary mixed diet, differences in melting points and utilization of fats are unimportant.

The satiety value of fats has been mentioned previously and is a result of their tendency to leave the stomach slowly. The larger the proportion of fat in a meal, the slower is the gastric emptying. Even when the proportion of fat was over two-thirds of the calorie value of a 1500-calorie meal, no discomfort was experienced by the 30 normal subjects in one test.[9] This is about twice the average proportion consumed in this country. When meals are high in protein which also leaves the stomach slowly, considerable variation in the associated fat intake may have no effect on emptying time.[10]

The form in which fat is consumed does not appear to be important in relation to gastric emptying or comfort. Prejudice against properly fried foods appears to have no scientific basis. Contrary to popular opinion,[11] children as well as normal adults have no more digestive difficulty with fried foods than with mixtures containing the same amount of fat in other forms.

[8] Bailey, *Industrial Oil and Fat Products*, Interscience Publishers Inc., New York (1951), p. 254.

[9] Annegers and Ivy, *Am. J. Physiol.*, 150: 461 (1947).

[10] Killian and Knapp, *J. Am. Oil Chemists' Soc.*, 24: 71 (1947).

[11] Richardson, *J. Pediat.*, 24: 199 (1944).

Although there seems to be little evidence that eating relatively high proportions of fat, as is the practice of many Americans, is responsible for digestive difficulty, some cases of persistent lack of appetite in children have been overcome by changing to low-fat diets. Furthermore, high-fat meals are nearly always high-calorie meals which are likely to lead to obesity. For this reason, many adults should restrict their consumption of these foods. On the other hand, a certain proportion of fat, enough to provide perhaps at least 20 per cent of one's calories, is essential to prevent the discomfort of a return of hunger before the usual time of eating.

Sanitary Quality

Microorganisms do not thrive on fat alone. In the processing of edible fats and oils, high standards of cleanliness are essential to prevent contamination with dust and other materials stimulating oxidations and to prevent the absorption of disagreeable odors. Because extraneous organic matter is likely to contain substances catalyzing the changes leading to rancidity, it is kept at a minimum under good factory conditions and consequently is not present to serve as a medium for bacterial development. Creamery butter is now generally made from pasteurized cream. Dairy butter, usually made from unpasteurized cream, could carry pathogenic organisms. Dairy products used in the manufacture of margarine are pasteurized as a routine factory procedure.

Although rancid fats are probably unwholesome, they are not likely to be eaten because their flavor is so repulsive. In general, fats and oils are seldom responsible for health problems caused by poor sanitary quality.

Palatability

Except olive oil, the vegetable oils consumed as salad oil or hydrogenated fat are almost entirely lacking in flavor. Margarines, as previously discussed, resemble butter because they contain added diacetyl and cultured milk products, but brands differ and nearly everyone can distinguish them from genuine butter. Lard has a characteristic flavor which interferes with its use in certain products but not in others.

Fats and oils contribute palatability qualities other than flavor to the products in which they are incorporated. These will be discussed in connection with their culinary uses.

Economy

The range in price among fats and oils of similar nutritive quality is wide, the spread being largely based on demand as related to palatability and, in some cases, as influenced by advertising. Thus olive oil commands a price two or three times that of a salad oil, and butter two or three times that of a fortified margarine. The very bland and highly advertised hydrogenated vegetable shortenings may be sold at prices almost double those of lard and some brands of margarine. The highly processed lards sold under special brand names are in the price class of the hydrogenated vegetable shortenings and interchangeable with them in culinary uses. In general, the cheaper fats compare favorably with cereals and sugar as inexpensive sources of energy.

THE CULINARY ROLES OF FATS AND OILS

Fats and oils serve in four major culinary roles: (1) as spreads, (2) as shortenings, (3) as salad oils, and (4) as frying mediums. As stated previously, butter, lard and suet, and olive oil formerly constituted the major types available for all purposes. The tendency of the modern market is to develop an ever larger number of specialized products so that there is not only improved adaptation to the major role but also differentiation to improve performance in the making of different kinds of products, when the major role is the same. For example, a shortening tailored by the manufacturer for best results in cake making is not equally adapted to making pie crust. Consequently, for the wholesale market two types are available, as mentioned previously.

Fats As Spreads

Butter and margarine constitute the fats available for spreads. Their function is to add to the flavor, nutritional contributions, and satiety value of breadstuffs. Differences between butter and margarine in nutritive quality, digestibility, sanitary quality, and economy have already been discussed in the section on the appraisal of fats and oils as food.

The palatability differences between butter and margarine are of interest in relation to their use as spreads. Higher grades of butter are rated superior in flavor to margarine by most people. Spreading

qualities of margarine differ with the brand and in some types may be considered not so desirable as those of butter. In some states, color must be added by the purchaser. If it is uncolored, the addition of color to margarine is at least a nuisance.

Fats and Oils As Shortenings

The functions of fats and oils as shortenings are to add to the nutritional and satiety values of flour mixtures and to contribute characteristic palatability qualities of flavor and texture to them. Butter, margarines, lard, hydrogenated vegetable fats, compounds, and purified vegetable oils are all used as shortenings. Their differences in nutritive quality, digestibility, and sanitary quality have been previously discussed. However, in relation to their use as shortenings, differences in their palatability and economy are significant.

Hydrogenated vegetable fats and refined vegetable oils used as shortenings are flavorless and hence do not contribute to the flavor of the product in which they are incorporated. Butter and margarine, especially butter, may contribute markedly to flavor, and butter is a preferred shortening in some mixtures for that reason. Lard of good quality does not affect flavor adversely in pie crust, biscuits, and muffins, but the method of combining with other ingredients must be suitably adjusted to avoid inferior flavor when lard is used in cake making.

Plain lard and the lower-priced margarines are usually the least expensive shortenings. There is general agreement that plain lard is equal if not superior to any other type of shortening available on the retail market for pie crust. It is also suitable for biscuits, and for cakes for which special recipes have been devised. For these products it is a "best buy." Margarine is satisfactory for cakes made by the creaming method and for most other flour mixtures except pie crust, for which lard is a better choice. Butter is the most expensive shortening but may be chosen for its superior flavor in the creamed type of cake and cookies when cost is not the primary consideration.

Hydrogenated vegetable shortenings and special-brand processed lards, now also superglycerinated (cake-conditioned), creamed, and supplied with antioxidants as well as deodorized, cost considerably more than plain lard or the cheapest margarines, but they have the advantages of being the most all-round shortenings satisfactory for all types of products and the only kinds adapted to making

"one-bowl" cakes, those combined by simple beating of ingredients with no preliminary creaming. When used for conventional method (creamed) cakes, they require less effort in creaming because they have had air incorporated in them at the factory. These shortenings also keep without refrigeration and are uniform within the brand. Plain lards and butter are more variable. Hydrogenated shortenings are also preferable for making bulk dry mixes in the household because mixes containing them do not require refrigeration. See Chapter 15, Part F, for a more detailed discussion of shortenings in flour mixtures.

Fats and Oils in Salad Dressings

The types of salad dressings used in home food preparation are:

(*a*) Sour cream dressings which consist of sour cream with or without added acid and seasonings.

(*b*) Hot animal fat dressings which consist usually of bacon fat, vinegar, and seasonings, served hot.

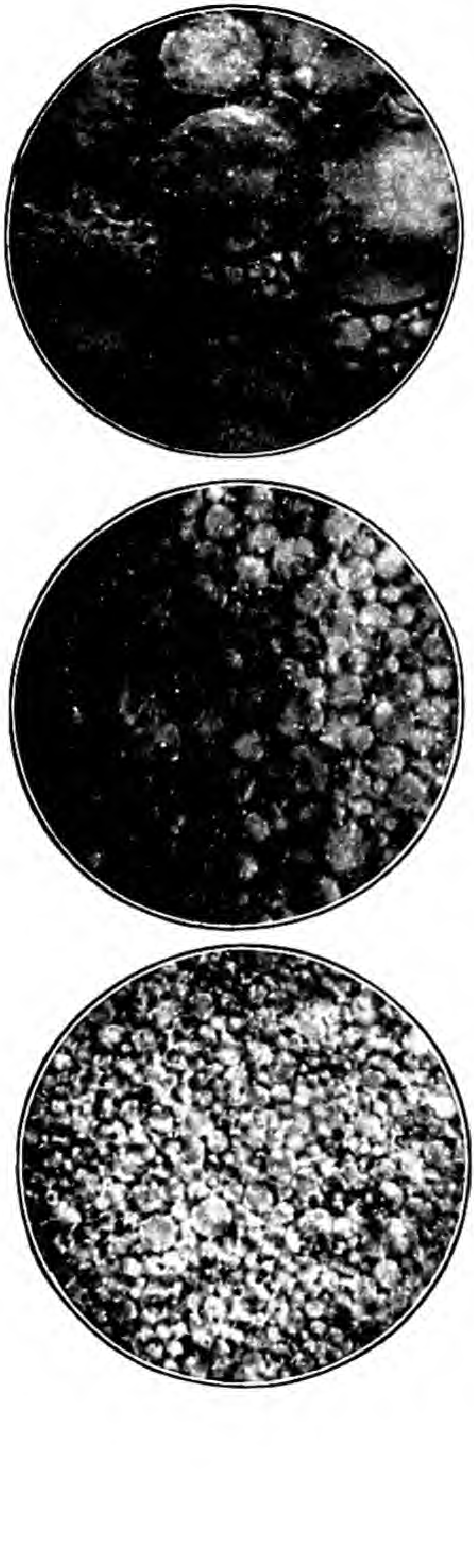
(*c*) Cooked dressings which are cooked mixtures of egg, vinegar, starch, fat or oil, and seasonings.

(*d*) French dressings which are emulsions of oil, acid, such as vinegar or lemon juice, and seasonings. Variations include added chopped foods such as chives, hard cooked egg, cheese, etc.

(*e*) Mayonnaise which is an emulsion of oil, egg, acid, and seasonings. Variations include added chopped foods as in French dressings.

French dressings and mayonnaise are of special interest here because their qualities are dependent upon the selection and emulsification of salad oil. They are essentially emulsions of oil in a small amount of water containing acids and other flavoring materials. Oils form neither true nor colloidal solutions in water, but they can be emulsified in it, that is, mechanically dispersed in it in the form of small droplets. There are two operations in the formation of a stable emulsion: (1) subdivision of one liquid into minute droplets and dispersion of the droplets in the other liquid and (2) stabilization to give permanence to the dispersion.

Subdivision is commonly produced by some form of agitation such as beating, whipping, or shaking, or by squeezing through fine pores as in homogenization. The larger the globules, the more often is their tendency to coalesce greater than the repelling effect of their charges; hence the smaller the globules formed, the more permanent the emulsions will be. (See Fig. 37.) Because it produces the small-



(a) (b) (c)

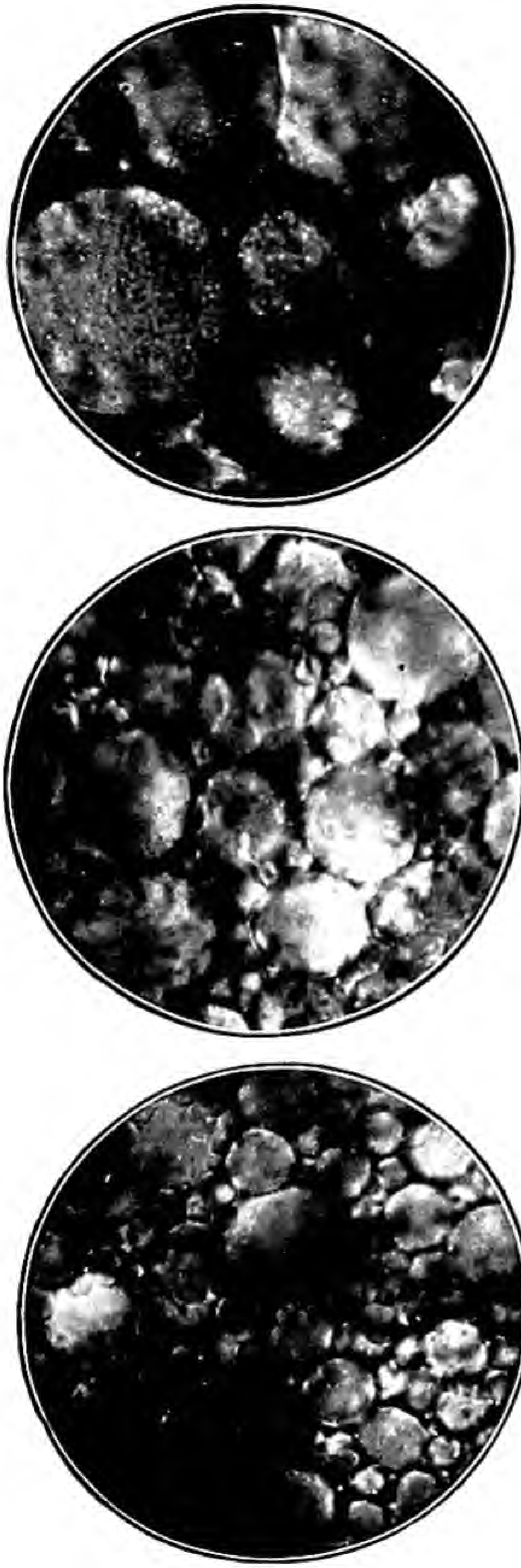
Fig. 37. Photomicrographs of different samples of commercial mayonnaise (×1000). (a) High-grade product; (b) Product of indifferent quality; (c) Poor-quality product. (Courtesy D. M. Gray.)

est globules, homogenization is superior to the other methods of subdivision; power beaters are likely to give more stable emulsions than hand beaters.

When the subdivision is produced by shaking or beating, obviously both liquids are subdivided to form droplets. Emulsions are produced and stabilized by some third substance of such a nature that it will concentrate upon the surfaces of the droplets of one of the two liquids. The droplets of the other liquid coalesce, becoming the dispersions medium. The nature of the *emulsifier* or *stabilizer*, as the third substance is called, is the principal factor determining which droplets, either of oil or water, will remain dispersed while the others coalesce. Among the substances stabilizing oil-in-water emulsions are hydrophilic colloids and fine powders like paprika. All emulsions of the salad-dressing type are of the oil-in-water kind. Gelatin, egg, flour, cornstarch, soybean flour, gum tragacanth, gum arabic, pectin, Irish moss, casein, condensed milk, mustard, and paprika may be employed to stabilize them. Egg yolk is generally rated as the most efficient of the group. Fresh eggs several days old are said to be superior to either new-laid or storage eggs for making mayonnaise. In commercial production, however, frozen, dried, or storage eggs are commonly employed.

With household equipment, an emulsion is most perfectly formed when small quantities of oil are added in alternation with periods of beating at the beginning. In the making of mayonnaise, progress is facilitated by diluting the egg with all of the vinegar or lemon juice at the start. This serves to give maximum volume to the hydrophilic colloids and other emulsifiers such as lecitho-proteins, present in the egg. After the first few teaspoonfuls of oil are emulsified, the only essential precaution is that the volume of oil added at one time should not be in excess of a certain proportion of the volume of emulsion already formed. The correct proportion varies but never equals the volume of the formed emulsion. When these conditions are met, temperature of utensils and ingredients may be ignored, although having them at room temperature lowers the viscosity of oil and facilitates emulsification. The smaller the droplets and the larger the proportions of oil emulsified, the stiffer the mayonnaise.

Demulsification or separation, also commonly known as the breaking of an emulsion, is a result of coalescence of the oil droplets. It may be caused by imperfect preliminary emulsification, wrong pro-



(a) (b) (c)

Fig. 38. Photomicrographs of mayonnaise showing effect of storage temperature (× 1000). (a) 72 hours holding at 40 degrees F.; (b) 72 hours holding at 75 degrees F.; (c) 72 hours holding at 98 degrees F. (Courtesy D. M. Gray.)

portions of ingredients, damage to the emulsifying agent during storage, or excessive vibration. Too rapid addition of the oil or the wrong type of agitation results in an imperfect preliminary emulsion. Storage in places that are too warm or in places at or near freezing, and exposure to the air, which permits evaporation or perhaps infection with bacteria which cause decomposition, injure the emulsifier. (See Fig. 38.) With reference to excessive vibration, it should be remembered that agitation may be employed to break as well as to make an emulsion. With any given mixture of ingredients and emulsifying apparatus there is probably an optimum speed of agitation for emulsification.

If the emulsion begins to break, the demulsification is progressive. To secure re-emulsification, it is necessary to start the process again by adding the broken emulsion in small amounts at one time to a tablespoon of water, vinegar, or diluted egg, just as though it were oil.

The Appraisal of Salad Dressings

The nutritive contributions of salad dressings are restricted almost entirely to energy in the form of fat calories. According to the federal standard of identity, commercial mayonnaise must contain at least 65 per cent by weight of edible vegetable oil. The only emulsifier permitted is egg or egg yolk. Other ingredients may include vinegar, lime or lemon juice, sugar or sirup, salt, and a variety of flavorings, so long as they do not impart the color of egg yolk. If citric acid is added it must be indicated on the label. Mayonnaise furnishes about 92 calories per tablespoon.

Commercial salad dressing must by legal definition contain at least 30 per cent of oil and 4 per cent of liquid egg yolk. Starch pastes may be used as thickening and limited amounts of an emulsifier may be added. Otherwise the ingredients are similar to those in mayonnaise except that limited amounts of certain emulsifiers may be added if so indicated on the label. It furnishes about 58 calories per tablespoon.

French dressings moving in interstate trade must contain at least 35 per cent of oil. They may contain the same sources of acid as mayonnaise and may or may not contain emulsifiers, but if present they must be indicated on the label. Commercial French dressings have a calorie value of about 60 calories per tablespoon. Household

products customarily contain a larger proportion of oil and are higher in calories.

Cooked ("boiled") salad dressings of the type made in the household which are comparatively high in egg and low in fat furnish about 28 calories per tablespoon.

Mineral oils, which are not digested and consequently have no energy value, have sometimes been used to make salad dressings which are "nonfattening." But the frequent use of mineral oil in any form in meals or soon after eating is an undesirable practice because the oil selectively dissolves carotenes and fat-soluble vitamins and thus restricts their absorption. Furthermore, mineral oils have a laxative action and other effects which may be detrimental to the body. Their commercial use in food is now prohibited on the federal level.

In digestibility, all types of salad dressings made with food oils are probably similar to other fatty foods. Since all fats must be emulsified before digestion, it is possible that mayonnaise is somewhat more rapidly attacked by the digestive enzymes than oil alone.

Cleanliness and general sanitation are so important in the production of desirable flavor in these foods that commercial manufacturers probably have sufficient incentive to keep their standards high. The acidity of mayonnaise and other commercial salad dressings is sufficient to retard most forms of bacterial spoilage and to prevent long-time survival of food poisoning bacteria.[12]

Palatability qualities of significance in salad dressings include color, flavor, and consistency. The color of mayonnaise, mayonnaise-type salad dressing, and household cooked salad dressing is dominated by that of egg yolk and should be golden yellow. Mayonnaise and mayonnaise-type salad dressing should be stiff enough to hold their shape. There seem to be no characteristic differences among salad oils in their effect upon consistency of emulsions made with them. The flavor should be characteristic of the ingredients and free from any trace of rancidity. Oil and egg are the most expensive ingredients in the mayonnaise-type dressings. Commercial mayonnaise-type salad dressing should be considerably cheaper than true mayonnaise. Olive oil is little used in commercial dressings and, as already discussed, is the most expensive salad oil. Homemade dressings are considerably cheaper than the commercial products, particularly if oil can be bought in large units.

[12] Wethington and Fabian, *Food Res.*, 15: 125 (1950).

Fats and Oils in Frying

Fat is employed as the cooking medium in pan frying and sautéing, which are cooking and browning in a small amount of fat, and in deep-fat frying, which is cooking by immersion in hot fat. The principal properties of fats that are important in frying quality are (*a*) resistance to decomposition at the temperature employed, and (*b*) the flavor imparted to the cooked food.

Resistance of Fats to Decomposition during Heating

When fats or oils are heated, a temperature is reached at which visible fumes appear. This has been defined as the *smoke point.* The smoke consists of volatile products of decomposition. The fat molecules are hydrolyzed, yielding free fatty acids which accumulate in the fat and glycerol which is converted to acrolein and forms an irritating component of the smoke. The free fatty acids give undesirable flavor to the products and catalyze further decomposition. In one investigation more than 2 per cent of free fatty acid (calculated as oleic acid) was reported to give definite objectionable flavor.[13] A thermometer should always be used in deep-fat frying to prevent overheating.

The temperature most desirable for frying depends upon the nature of the food, that is, whether it is cooked or uncooked, and upon the size of the pieces. Higher temperatures giving shorter cooking periods are suitable for cooked foods which are merely to be heated and browned, or for any foods in small pieces. The highest frying temperature needed for any food is about 390 degrees F. (199 degrees C.). A fat should resist decomposition at somewhat higher temperatures if it is to be considered adapted to frying, because the smoke point lowers with use.

As already mentioned, resistance to decomposition at high temperatures is not an essential qualification of a fat for pan frying or sautéing. Therefore, butter, margarine, olive oil, and drippings are included in the list of fats suitable for such uses, provided the temperature is kept low enough to prevent smoking.

The smoking temperature of a fat has been found to vary with the kind of fat or oil, the amount of previous heating to which it has been subjected, the amount of surface exposed in frying, and the

[13] Porter et al., *Ind. Eng. Chem.*, 24: 811 (1932).

presence or absence of finely divided particles of food in the fat. The smoking temperatures of a number of fats and oils under standardized conditions are given in Table XLIII.

Table XLIII. Smoke points and free fatty acid as oleic

[From Swartz, *J. Home Econ.*, 40: 252 (1948)]

Fat	Container and amount of fat: AOCS * Cup 70 g.,† degrees F.	Enameled kettle ‡ 1000 g., degrees F.	Enameled kettle ‡ 2000 g., degrees F.	Free fatty acid, %
Lards				
1. Steam-rendered	333	304	313	0.49
2. Steam-rendered	343	313	320	0.23
3. Steam-rendered	327	307	313	0.45
4. Leaf	374	324	352	0.20
All-hydrogenated fats				
1.	354	311	309	0.06
2.	340	306	307	0.09
3.	432	397	397	0.03
4.	356	309	311	0.09
Blended shortenings				
1. Animal-vegetable	390	369	381	0.12
2. Vegetable-animal	441	406	410	0.07
3. All-vegetable (major component named first)	417	381	392	0.08
Oils				
1. Cottonseed	426	397	406	0.05
2. Peanut	378	334	349	0.17
3. Corn	408	360	376	0.17
4. Soybean	439	405	415	0.17

* American Oil Chemists' Society.

† Two to four determinations on each fat. Difference between highest and lowest smoke point observed, 0 to 13 degrees F., average 3.8 degrees F.

‡ The enameled kettle was 20 cm. (approximately 8 inches) in diameter.

The Kind of Fat or Oil. According to the data in Table XLIII, cottonseed and soybean oils and one brand of all-hydrogenated fat were the only products tested which had a sufficiently high smoke point to be acceptable for deep frying. Brands of cottonseed oil are available on the retail market, but, as mentioned previously, soy-

bean oil has not been considered satisfactory because it develops a "beany" odor. The palatability of fried products is not always affected adversely by a relatively low smoking temperature. A number of experimenters have reported that peanut oil gives excellent French fried potatoes and potato chips, usually superior to those fried in cottonseed oil.[14]

Formerly hydrogenated vegetable fats as a class had high smoke points and, according to the manufacturer of one well-known brand, the change is a result of superglycerination.* The claim is made that the vapor appearing at the relatively low temperatures is composed of mono- and diglycerides and does not indicate decomposition of the basic fat itself. Hence this smoke is not associated with accumulation of free fatty acid and deterioration in flavor. For this reason, household vegetable shortenings continue to be promoted for frying. Probably most homemakers do not consider the vapor objectionable for the usually limited amounts of deep frying that they practice. Manufacturers, as noted previously, make two types of shortening for the wholesale trade, one of which is highly hydrogenated without superglycerination and hence particularly adapted to deep frying.

The original smoking temperature of a particular kind of fat is related to the amount of free fatty acid that it contains, those having the larger proportion of free fatty acid generally having the lower smoking temperatures. This relationship has also been confirmed by neutralizing olive oil with alkali and testing the smoking temperature of the fatty portion which was extracted by ether. This portion was found to have nearly the same smoking temperature as cottonseed oil, 138 degrees F. (58.8 degrees C.) above the smoking temperature of the original olive oil.[15]

The Amount of Previous Heating. The smoking temperatures of all fats decrease in time as they are heated. A leaf lard heated for 5 hours may have a drop in smoking temperature from 428 to 405 degrees F. (220 to 207 degrees C.). This change in smoking temperature, like the original smoking temperature, is associated with the amount of free fatty acid present. Thus the decomposition that takes place with use of the fat for frying is responsible

[14] Alexander et al., *J. Am. Dietet. Assoc.*, 26: 182 (1950); Grim and Eheart, *J. Am. Dietet. Assoc.*, 19: 618 (1943); King et al., *J. Agr. Research*, 53: 369 (1936).

* Private communication.

[15] Blunt and Feeny, *J. Home Econ.*, 7: 535 (1915).

for at least part of the change in its smoking temperature. Although the actual increase in acidity in as much as 20 hours of use, is rather small, the long-continued presence of food catalyzes these changes. When water is present and some acid has been formed, the decomposition proceeds more rapidly. The degree of high temperature does not seem to be so important as the time of exposure to it. In one study of the frying of doughnuts, however, it was found that reheating and reuse of any of a number of different types of fat up to 12 hours did not affect the palatability of the product.[16]

The Relative Amount of Surface Exposed in Frying. The smoking temperature is also affected by the diameter of the pan, wider pans giving lower smoking temperatures. Thus the statements of manufacturers about the smoking temperatures of their fats are of little significance unless the size of the vessel used in making the determination is mentioned. Frying should be carried on in pans with vertical sides because they have the greatest capacity per unit of surface.

The Presence of Finely Divided Particles of Food in the Fat. The presence of finely divided foreign substances such as flour lowers the smoking temperature of a fat. This is explained as a result of the increase in surface of exposure of the fat on the particles, the effect being similar to that of the increase in surface resulting from the use of a kettle of greater diameter. To prolong the frying life of a fat, it should be strained with each use. Clarifying fat by cooking potatoes in it is a common method of removing foreign flavors.

The stability of the fat during frying also affects the keeping qualities of the fried product. Fried foods such as potato chips, which are held for considerable periods, retain a fresh taste longer when fried in vegetable oils such as peanut or cottonseed oil than when fried in lard, for example. The used fats should be kept in lightproof, airtight containers in a cool place between heating periods.

Effects of the Fat on the Flavor of Fried Food

Differences among the kinds of fats or oils available for frying in their effect on flavor are much less important than whether they have

[16] Thiessen, *Food Res.*, 4: 135 (1939).

developed rancidity or been absorbed to an excessive degree. Fats that have become even slightly rancid are not suitable for frying.

The amount of fat absorbed in frying is of significance in relation not only to palatability, but to the digestibility, nutritive quality, and cost of the product. In general, absorption should be kept as low as possible. Overabsorption of fat is undesirable because it makes the food have an unpleasant greasy feel in the mouth, possibly delays emptying of the stomach to such an extent that discomfort may arise, increases the calorie value of the food without supplying other nutrients, and increases the cost of the food.

Factors affecting absorption during frying include the time required for cooking, the relative amount of surface exposed and the composition of the food. The shorter the time of exposure and the smaller the proportion of surface, the less is the amount of absorption. The temperature of the fat affects absorption indirectly because it determines the relative amount of time necessary to cook and brown food. In such mixtures as doughnuts, the proportions of sugar, liquid, and leavening affect the amount of fat absorbed. The BHNHE found that the amount of fat absorbed by potato chips did not vary with the kind of fat used for frying when peanut, corn, and cottonseed oils and lard were compared.[17]

SUMMARY OF POINTS TO CONSIDER IN SELECTING AND USING FATS AND OILS

1. Fats and oils are nutritionally useful primarily as concentrated and, in some forms, economical sources of energy. Because they are slow to leave the stomach they give satiety value to meals. They also contribute desired palatability qualities to many foods with which they are served or to food mixtures in which they are incorporated.

2. Animal fats including butter and lard require refrigeration to retain their fresh flavor except in the case of lards to which antioxidants have been added. Vegetable fats and oils are less perishable because they contain natural antioxidants and may be stored at room temperatures for longer periods.

3. Margarines which are fortified with 15,000 USP units of vitamin A per pound resemble butter in nutritional value and digestibility. The margarines are much less costly than butter but are not generally considered as palatable as butter of high grade.

[17] King et al., *J. Agr. Research*, 53: 369 (1936).

4. There are no significant differences among salad oils except in taste and cost. Olive oil of high quality is preferred at least by connoisseurs, but is much more expensive than refined vegetable oils.

5. Plain lard is the least expensive of all shortenings except the lowest-priced margarines. It contributes superior palatability qualities to pie crust and is satisfactory as the shortening in most other kinds of flour mixtures but requires particular manipulative technics to mask its flavor in cakes. The cheaper brands of margarine are also relatively economical shortenings. Superglycerinated lards and vegetable shortenings have the advantage of uniformity, high keeping quality at room temperature, absence of characteristic flavor in food mixtures, and superior emulsifying qualities for cake making. They are much more expensive than plain lard.

6. Cottonseed oil and highly hydrogenated vegetable fats which have not been superglycerinated have the highest smoking temperatures and are hence most suited for deep frying. At present such vegetable fats are not generally available on the retail market. Consumers who wish to buy an all-purpose cooking fat and who do relatively little deep frying will probably consider either the superglycerinated shortenings or a good grade of lard satisfactory.

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CHAPTER 14

SUGARS AND FOOD MIXTURES HIGH IN SUGAR

The composition and sources of sugars and sirups.
The structure of sugars and sirups.
The appraisal of sugars and sirups.
The processing of sugar.
The preparation of food mixtures high in sugar.
  Candies and cake frostings.
  Jellies, jams, and preserves.
  Sweet beverages.
Summary of points to consider in selecting sugars and foods high in sugar.

The change in the rate of consumption of sugar in the United States during the last hundred years represents one of the most rapid and significant alterations that has ever taken place in the diet of a people. The estimated annual per capita consumption rose from less than 9 pounds in 1923 to 93.5 pounds in 1948. This amounted to an increase from about 44 calories per day to about 460 calories per day. In addition, the per capita consumption of sirups amounted to about 12 pounds in the latter year. (See Table XLIV.) Consump-

Table XLIV. Approximate consumption of sugar and sirups in pounds per capita, 1918–1948

[From *U. S. Dept. Agr., Misc. Pub.* 691, 1949]

Sugar and sirups	1918	1928	1938	1948
Sugar *	71.7	106.9	93.8	93.5
Corn sirup	3.1	1.6	2.1	1.6
Sorgho sirup	4.1	1.2	1.1	0.8
Molasses	0.2	.....	1.1	0.3
Maple sirup †	0.6	0.4	0.3	0.2
Refiner's sirup	(0.2) ‡	(0.3)	(0.2)	0.3
Honey	(1.2)	1.7	1.5	1.3
Corn sirup	7.5	7.9	7.6	8.2

* Excludes sugar used in production of frozen fruit, canned fruit, canned fruit juices, canned vegetables, salad dressings, unskimmed, sweetened condensed milk, and tobacco products.

† Includes sirup equivalent of maple sugar.

‡ Imputed values are in parentheses.

tion of sugar and sugar-rich foods by families increases markedly as the total value of food consumed increases.

Sugar consumption varies greatly from country to country. The United Nations Food and Agricultural Organization estimated in 1952 that sugars and sirups contributed 16 to 18 per cent of the calories consumed in the United States, Sweden, Canada, Union of South Africa, and Australia. In Italy, Norway, France, Egypt, and India, the proportions ranged from 5 to 9 per cent. In China and Japan, the figures were 1 and 2 per cent.

THE COMPOSITION AND SOURCES OF SUGARS AND SIRUPS

The six natural sugars of importance in foods, glucose (dextrose), fructose (levulose), galactose, maltose, sucrose, and lactose, together with their empirical formulas, have been listed in Chapter 1. Of the three monosaccharides, glucose is commercially the most important. Commercial glucose is made from starch. It forms a large part of the solids in corn sirups and is available in a purified crystalline form called corn sugar or dextrose. Fructose is manufactured from inulin, a starchlike substance present in dahlia bulbs and tubers of the Jerusalem artichoke. It is very difficult to crystallize from its sirups, however, and in the solid form has not become commercially important. The third monosaccharide, galactose, is of significance only as a part of the lactose molecule and is not of any commercial importance.

Sucrose was formerly the only "sugar" recognized legally by that name, but the Secretary of Agriculture has ruled that corn sugar requires no designation other than "sugar" on labels of packages of foods containing it. Sucrose is prepared in a 99.9 per cent pure state from both beets and sugar cane. Crystals form in the concentrated juices of these plants and are refined on a large scale to give a variety of market products. In the manufacture of cane sugar, for example, there are essentially five steps. First, the juice is extracted from the cane by crushing; second, the juice is purified by heating with lime; third, the purified juice is evaporated to a sirup; fourth, this sirup is concentrated until crystals form; fifth, the crystals are removed by centrifuging, leaving molasses. The molasses can be further concentrated and centrifuged to remove additional crops of

crystals. The sugar as separated from the molasses is known as raw sugar and must be washed, redissolved, decolorized, and recrystallized to produce the refined product with which we are familiar.

Refined sucrose is available in milled and pulverized forms. Milled sugar varies in size of crystals to include *fine*, the standard granulated sugar; *extra fine*, sometimes called "fruit powdered" which is used for sweetening cold drinks; and *coating*, which is used for cake icings. Granulated sugar may be pressed into tablets or cubes for sweetening hot beverages. Pulverized sugars include *powdered*, a relatively coarsely ground product used for sweetening fruits, breakfast foods, and cold drinks; and *confectioners' XXXX*, a very finely ground product used in uncooked frostings or icings. The latter sometimes contains 3 per cent of cornstarch added to prevent caking.

A small amount of raw cane sugar is sold on some markets, but the two most common types of unpurified sucrose are brown sugar and maple sugar. Brown sugar is cane sugar recrystallized from refiner's sirup, the sirup formed when raw sugar crystals are dissolved and recrystallized. The flavor and color of brown sugars are desired for certain culinary uses. The dark brown sugars contain more concentrated refiner's sirup than the light. Maple sugar, a sweet very highly prized for its flavor, is formed by concentrating maple sap. It consists of sucrose and a small amount of glucose and fructose, together with various impurities which give it the characteristic flavor and color.

Lactose is manufactured on a commercial scale as a by-product of various milk industries. Formerly it was marketed only in the *alpha* form, but more recently *beta* lactose has been made available at moderate prices. *Beta* lactose is much more readily soluble in water than *alpha* lactose and is used in making infant milk formulas. Maltose is an intermediate product formed in the manufacture of glucose from starch, and appears with glucose in corn sugar sirups.

In addition to the solid sugars, a number of sirups which have important table and culinary uses include (1) corn sirup, (2) sorgho sirup, (3) cane sirup, (4) honey, (5) maple sirup, and (6) molasses.

Corn sirup. Ordinary corn sirup is manufactured by hydrolyzing cornstarch with acid. This gives a mixture containing about 18 per cent dextrose, 32 per cent maltose and other sugars, and 30 per cent dextrins. White corn sirup is commonly a mixture of corn sirup

with a smaller quantity of sugar sirup to which flavoring is added. Golden corn sirup is a mixture of corn sirup with a small proportion of refiner's sirup, the liquid which remains after recrystallization of sucrose during the refining process.

A new type of corn sirup (trade name, "Sweetose") has been treated with an enzyme to convert most of the dextrins to dextrose. According to the manufacturer, it contains 30 per cent dextrose, 28 per cent maltose, 13 per cent other sugars, and 10 per cent dextrins. The larger proportion of sugars makes this about one and one-half times sweeter than ordinary corn sirup.[1]

Sorgho sirup or *sorghum*, the evaporated juice of sorghum cane, contains about 36 per cent sucrose and 27 per cent glucose and fructose, not more than 30 per cent water, and on the dry basis about 6.25 per cent ash (minerals).

Cane sirup is made by boiling down cane sap until it is about the consistency of molasses and contains not more than 30 per cent water and 2.5 per cent ash, and 65 to 70 per cent sugar.

Honey is the nectar of flowers concentrated by bees. It contains about 18 per cent water and 81 per cent carbohydrate; the latter includes about 2 per cent sucrose and 75 per cent glucose and fructose. Because it is a supersaturated sugar solution, honey tends to crystallize, or become "granulated." The crystals can be redissolved by allowing the container of the granulated product to stand in hot water. Granulation can be prevented by adjusting the water content to 20 per cent and pasteurizing for 3 hours at 122 degrees F. (50 degrees C.). Granulated honey is sometimes whipped to give it a fine texture and sold in this form. Honey is sold both in the comb and extracted, that is, removed from the comb. It is graded according to color and flavor, which vary with the source of the nectar.

Maple sirup is the sap of the maple tree concentrated until it contains not more than 32 per cent water and about 65 per cent sugar, which is almost entirely sucrose. It is graded by color, unless the flavor is inferior as a result of too late tapping.

Molasses is the residue after one or more crystallizations of sucrose have been made from concentrated cane juice. The composition varies widely, all types containing the sugars sucrose, dextrose, and

[1] Shank, *J. Home Econ.*, 34: 468 (1942).

levulose. First or light molasses is the concentrated sap remaining after one crop of sugar crystals has been removed. It is the sweetest and mildest in flavor and contains about 65 per cent sugars and 6.3 per cent ash.* Second extraction or medium molasses is the product left from concentration and crystallization of first molasses. It contains about 60 per cent sugar and 8.5 per cent ash.* Further concentration of this molasses with removal of a third crop of sucrose crystals leaves "blackstrap," containing about 55 per cent sugar and 10.5 per cent ash.* Blackstrap is very strong in flavor and was generally considered unsuitable for human consumption until it was more or less popularized by a current food fad.

In addition to these three grades of ordinary molasses, "open kettle" molasses is occasionally available. It is essentially concentrated cane sirup that has been evaporated to the point where crystallization begins and then aged, that is, fermented by certain strains of yeast, so that it develops a delicate rum flavor. Because it is not clarified or bleached, it may be darker in color than a regular "first" molasses.

Beside these major types of sirups, the market offers a variety of mixed sirups for use on pancakes, etc. They are mostly cane, refiner's sirup, or corn sirups which are often flavored with genuine maple sirup or synthetic maple flavoring.

THE STRUCTURE OF SUGARS AND SIRUPS

The sugars form true solutions in water. Honey and the other sirups mentioned above are highly concentrated solutions of this sort. Such factors as evaporation and low temperatures may cause them to become supersaturated, a condition which ultimately results in crystal formation. Crystals of sucrose in maple sirup and of glucose in honey are familiar examples. Modern study of crystal structure by means of X-rays indicates that sugar crystals are composed of molecules arranged to form a definite pattern. So long as the sugar is melted or in solution, the molecules move past each other in a hit-or-miss fashion. When crystallization occurs, these units assume certain characteristic spatial relationships. In such

* Sulfated ash. This overestimates the ash by 8 to 20 per cent. Data from Watt and Merrill, *U. S. Dept. Agr., Hdbk.* 8 (1950).

mixtures as fudge or fondant, sugar crystals are formed deliberately. Their size is an important culinary quality and is determined by the composition of the mixture and such physical conditions as temperature and agitation, which will be discussed later.

Sugars, like some other compounds, may not always be crystalline when in the solid state. When the transformation from liquid to solid is so rapid that there is no time for pattern formation, or when foreign substances interfere with arrangement, or under certain other conditions, solidification is merely a process in which viscosity increases, the kinetic motion of the molecules diminishes, and the solid state is reached without any design or pattern of arrangement. Such solids are called amorphous. The glassy product formed when sucrose crystals are melted and quickly cooled is an example. Some candies, such as peanut brittle, contain solid sugar in this structureless form.

THE APPRAISAL OF SUGARS AND SIRUPS

Nutritive Quality

As a class, sugars and sirups provide a substantial proportion of our energy but little else. (See Table XLV.) None of the ordinary commercial products contains a significant amount of protein, minerals, or vitamins. Honey, although it is a plant product which has been subjected to little or no processing, contains only insignificant amounts of minerals or vitamins. Molasses and maple sirup furnish moderate amounts of calcium and substantial amounts of iron. The particularly high calcium and iron values of blackstrap molasses are notable, but they are to be discounted as of no importance because the product is generally considered inedible.

In 1948, sugars and sirups provided 15.2 per cent of the energy, about 5 per cent of the iron, and less than 1 per cent of any other nutrient consumed in the United States.[2] In view of the limited contributions of these foods other than energy, it is evident that their deficiencies must be compensated by choosing the remaining foods among those which furnish more than their share of almost every nutrient as compared with calories, or the diet as a whole will be inadequate. Sugar is not an essential food. Until a century and a half ago it was almost unavailable in purified form.

[2] *U. S. Dept. Agr., Misc. Pub.* 691 (1949).

Table XLV. The nutritive contributions of sugars and sirups, given as percentages of the *Recommended Allowances* for a physically active man

[Babcock, *N. J. Agr. Expt. Sta. Bull.* 751 (1950) and miscellaneous sources]

Food, description and measure	Food nutrients: Energy	Protein	Calcium	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Ascorbic acid
Sugar, granulated, 2 tablespoons (25 grams)	3	0	0	0	0	0	0	0	0
Dark brown sugar, 2 tablespoons (packed) (28 grams)	3	0	1	7	0	0	0	0	0
Corn sirup, 1½ tablespoons (34 grams)	3	0	1½	10	0	0	0	0	0
Honey, 1½ tablespoons (32 grams)	3	0	0	2	0	0	1	0	2
Maple sirup, 1½ tablespoons (35 grams)	3	0	6	10	0	0	0	0	0
Molasses, 2 tablespoons (40 grams)									
First	3	0	7	15	0	1	1	0	..
Second	3	0	12	20	..	..	..	..	..
Third	3	0	23	38	..	8	6	5	..

In the attempt to find a dietary explanation for the increase in the incidence of such diseases as diabetes and dental caries, our increased sugar consumption has been incriminated. Diabetes is commonly associated with overweight, and sugar is to be blamed primarily because its palatability encourages overeating. The relation of food to tooth decay is not entirely understood, but a lower than average amount of decay has been associated by many researchers with the habit of eating relatively small amounts of sugar and sugar-rich foods. This association is explained in two different ways: one interpretation maintains that high intakes of sugar have a detrimental effect because the whole diet is less well-balanced in the essentials required for building sound teeth; the other explanation is that sugar creates an unfavorable mouth environment for teeth by stimulating the production of acids which attack and dissolve them. Whatever explanation is correct, the practical application is obvious.

Sugar not only displaces more balanced foods, but its unrestrained use cultivates a taste for sweets that is natural, or readily acquired by almost everyone, and that removes the appetite for unsweetened foods. Sugars are good sources of energy, but so is starch, and both should be taken largely in natural foods that are furnishing other essentials, especially vitamins of the B complex which function in the metabolism of carbohydrate. Fruits and milk products contribute sugars naturally mixed with these vitamins, and with the minerals so frequently lacking in the average dietary. These foods in their natural or prepared forms are nutritionally preferable to sweets both for desserts and between-meal lunches whether for school child or worker.

Digestibility

The sugars and sirups contain no roughage and are almost completely digested. When eaten alone and in considerable amounts (100 grams) sugars depress the secretion of the gastric juice and delay evacuation of the stomach. Sugars and sweets in general should be taken in small amounts at a time, and at the end of meals when they will be well diluted with other foods. This not only minimizes their inhibiting effect on gastric secretion but lessens their tendency to withdraw water from the lining of the stomach, which causes irritation.

Because dextrose requires no digestion, it has been assumed that it is the most rapidly absorbed sugar. Experimental evidence does not substantiate this view, for it has been found that the dextrose and levulose from digested sucrose are available for physiological use before pure dextrose itself.[3] The principal significance of this finding is to refute the claim that corn sugar has a special capacity to relieve fatigue or maintain a high degree of muscular efficiency. The Council on Foods of the American Medical Association maintains that dextrose has no such unique powers.[4]

Both sucrose and maltose are hydrolyzed and absorbed more quickly than lactose. Because the slow absorption of lactose stimulates the development of acid-forming bacteria in the intestines, the development of the less desirable putrefactive types is depressed and calcium absorption is promoted.[5] This effect is believed to be beneficial to some adults and may give lactose an advantage in infant feeding.

Sanitary Quality

The modern process of refining sugar so completely removes impurities under conditions where the opportunities for infection from human contact are negligible that this food offers few sanitary hazards. Packaging in cardboard as now practiced is an effective method of preventing contamination during marketing.[6] Bulk molasses and other sirups are not handled with such care, but the natural antiseptic quality of high concentrations of sugar makes this group of foods relatively safe. They are probably rarely responsible for transmission of disease.

Problems of unwholesomeness due to contamination with a harmful mineral occur in the manufacture of maple sirup and at least occasionally in connection with honey. Spray residues apparently do not represent a hazard to honey consumers because the bees are killed before they deposit the contaminated nectar. But, in a few samples, lead, presumably derived from equipment or containers, has been found to exceed the federal tolerance.[7]

The problem of metallic contamination of maple sirup also involves lead. Sources of contamination are paints and solders used

[3] Anon., *Nutrition Revs.*, 3: 245 (1945).

[4] Council on Foods, *J. Am. Med. Assoc.*, 108: 556 (1937).

[5] Kline et al., *J. Biol. Chem.*, 98: 121 (1932).

[6] Wolk and Winslow, *Food Res.*, 9: 115 (1944).

[7] Schuette and Zimmerman, *Proc. Inst. Food Technol.* (1940), p. 149.

in spouts, buckets, pipelines, tanks, and evaporators. Certain types of coating materials have been found to minimize this difficulty.

Palatability

Sugar was first used almost exclusively as a condiment on account of its sweetening capacity. Even today the competition among sugars for first place in the choice of the people is based so largely on this quality that it has been called "the race for sweetness." The sweeter a sugar is, the higher it ranks in demand. Sweetness is a quality which is difficult to measure accurately. One method of rating it is to determine the "threshold value," or the lowest concentration of the sugar that tastes sweet to a number of subjects under carefully controlled conditions. Sucrose is rated 100, and other sugars are compared with it.[8] (See Table XLVI.) According

Table XLVI. The relative sweetness of sugars

[After Biester et al.]

Sugar	Concentration reported sweet by all subjects	Numeral rating	Units sugar equivalent to one unit sucrose
Lactose	8.10	16.0	6.3
Galactose	4.05	32.1	3.1
Maltose	4.00	32.5	3.1
Glucose	1.75	74.3	1.3
Sucrose	1.30	100.0	1.0
Fructose	0.75	173.3	0.6

to this method, dextrose is about three-fourths as sweet as sucrose, maltose about one-third as sweet, and lactose about one-sixth as sweet. Fructose is almost twice as sweet as sucrose. More recent studies in which sweetness of different sugars was rated by experienced judges have shown that relative sweetness varies with concentration. Thus, in 20 per cent solutions, if the sweetness of sucrose was considered 100, fructose rated approximately 120, dextrose 92, *beta* lactose 60, maltose 56, and corn sirup solids 47. When both were in 40 and 50 per cent solutions, dextrose was rated equal in sweetness to sucrose.[9] In this study dextrose ranged from 62.5 per

[8] Biester et al., *Am. J. Physiol.*, 73: 387 (1925).

[9] Dahlberg and Penczek, *N. Y. Agr. Expt. Sta. Tech. Bull.* 258 (1941).

cent as sweet as sucrose in 2 per cent solutions to 100 per cent as sweet in 40 per cent solutions. (See Table XLVII.) The authors

Table XLVII. Relative sweetness of various sugars using sucrose in different concentrations as the standard for comparison *

[After Dahlberg and Penczek]

	Sucrose in solutions used as standards								
	2%	5%	10%	15%	20%	25%	30%	40%	50%
Levulose	....	111.1	114.9	117.2	119.8	....	....	...	...
Beta lactose	33.3	38.2	48.3	54.0	60.1	....	....	...	...
Dextrose	62.5	69.4	78.7	87.2	91.7	90.9	95.2	100	100
Corn sirup solids	28.5	31.8	39.8	45.0	47.3	49.0	54.5	...	...

* Based on sucrose as 100.

concluded: "Dextrose and corn sirups are least sweet in products with a low sugar content and increased percentages must be used to give comparable sweetness. When the foods contain relatively high sugar concentrations, these corn sweeteners are relatively sweeter and when used in combination with sucrose may actually replace it pound for pound. It is impossible, therefore, to make a definite rule regarding relative sweetness of sugars for the food industries, but each product must be considered individually."

The BHNHE tested the use of dextrose and corn sirup in a number of household products and made the following recommendations:

Corn sirups and dextrose may be used as the only sweetening in beverages, puddings, custards, and sauces. For sweetening equal to that of sugar, twice as much corn sirup or dextrose is required. If corn sirup is used, the other liquids must be reduced by one-fourth. In baked products—such as muffins, plain cake, and drop cookies—corn sirup may be substituted, measure for measure, for sugar with a reduction of one-third the liquid. Also, up to one-third the amount of sugar may be replaced by dextrose in these products, although a less sweet product will result. Various proportions of corn sirup and dextrose may be used in candies, icings, and mousses, depending on the consistency desired. Half the measure of sugar in stewed fruits may be replaced by dextrose or corn sirup. Fresh fruit may be sweetened with dextrose if desired.

In studying corn sirup and corn sugar in the preservation of fruits, it was found that 30 per cent by weight of the sugar required to can peaches and pears could be replaced by either of these products. In cherry and

strawberry preserves, a 50 per cent substitution by weight of corn sirup or 25 per cent of corn sugar was satisfactory. Up to 30 per cent of the sugar used in currant, loganberry, Concord grape, blackberry, and cranberry jellies could be replaced with either corn sirup or corn sugar, although 25 per cent was preferable. Quick sweet pickles were found acceptable with a 30 per cent substitution by measure of corn sirup or corn sugar.*

In general, the substitution of corn sugar (dextrose) for sucrose has the nutritional disadvantage that it may encourage the use of larger proportions to obtain the accustomed degree of sweetness. Our natural taste for sweets, together with the almost unlimited opportunity to indulge it, leads us to destroy the characteristic flavors of many of our foods, such as the nuttiness of the cereals, the tartness of fruits, and even the individuality of the vegetables, by a monotonous sweetness due to added sugar. Adherence to a rational sugar allowance of no more than 50 to 60 pounds per year *in all forms* would widen the gustatory horizons of all.†

Saccharin is a drug which is sweet in very low concentrations, because it is 200 to 700 times as sweet as sugar. It has no food value but is often used as a sweetening agent by those who are limited to a very small intake of sugar or none at all, for medical reasons. Although such patients have used small amounts of saccharin for years without harmful effect,[10] nutritionists do not recommend its general use as a sugar substitute. The Council on Foods of the American Medical Association has agreed that "the indiscriminate use of saccharin is not advisable and that its presence in any food product should be clearly indicated to consumers."[11]

Economy

Sugar is in the class of flour as being one of our least expensive sources of energy, but flour furnishes important amounts of protein and other nutrients and hence is a much better buy. Honey and maple sirup are relatively expensive sweets to be bought primarily for their palatability qualities, but molasses, which is intermediate

* Report of the chief, Bureau of Home Economics, 1941, p. 11.

† It should be remembered that nearly everyone eats considerable amounts of commercially sweetened foods including ice cream, candy, pudding mixtures, bakery products, soft drinks, canned fruits, etc., as well as sugar itself or household-made products containing it.

[10] Current Comment, *J. Am. Med. Assoc.*, 119: 1028 (1942).

[11] Council on Foods, *J. Am. Med. Assoc.*, 119: 345 (1942).

in cost, is worth consideration as a substitute for sugar in appropriate culinary mixtures on account of its mineral contributions.

THE PROCESSING OF SUGAR

In the household, sugar is subjected to two types of processing which change its composition, i.e., inversion and caramelization.

Inversion

Inversion is the process in which sucrose is broken down into glucose and fructose. These two sugars are always formed in equal amounts, and the mixture is known as invert sugar. A small amount of inversion is produced during long heating of a sugar-water solution, but the process is greatly accelerated by the addition of weak acids. The enzyme invertase also inverts sucrose.

Acids differ in their effect on rate of inversion. Not total acidity but hydrogen-ion concentration is the important factor in this as well as in many other changes in foods. The acids found in foods are relatively weak organic acids which have a low hydrogen-ion concentration and cause slow inversion. Raising the temperature, as in cooking, increases their inverting power. Thus a large proportion of invert sugar may be formed when fruit is sweetened and cooked.

Inversion by the enzyme invertase is important in the digestion of sucrose because disaccharides are not absorbed. The bee secretes this enzyme in her honey sac, where it inverts most of the sucrose in the plant nectar. Invertase is employed for the inversion of sucrose in the commercial manufacture of candy, as will be discussed more completely later. In the presence of invert sugar, the solubility of sucrose is increased and it tends to recrystallize more slowly. Inversion raises the boiling point and lowers the freezing point of sugar solutions. The latter property explains why using honey as a sweetener makes it more difficult to freeze ice creams and sherbets.

Inversion has no important effect upon the nutritive quality of sucrose. Monosaccharides are absorbable; consequently inversion of sucrose outside the body is a digestive process. So far as it is known, this does not result in any significant physiological gain. The fact that honey contains a large proportion of invert sugar

which does not require digestion, gives it no important dietary advantage over sucrose.

Inversion increases the total sweetening power of a quantity of sucrose somewhat, the superiority of fructose in this regard overbalancing the lack of sweetness of the glucose. One hundred pounds of sucrose inverted has been said to equal 130 pounds of the original sugar in sweetening power,[12] but in some concentrations it seems to differ little from the same concentrations of sucrose.

Caramelization

The melting point of sucrose ranges between 160 and 180 degrees C. (320 and 356 degrees F.). Sugar which has been melted slowly and cooled to form an amorphous mass is known as barley sugar. When sugar is heated to temperatures above the melting point, it begins to decompose and give off water. At 170 degrees C. (338 degrees F.), a mixture of substances of a brownish color, which is known as caramel, begins to be formed. Caramel is not a substance of definite composition but a mixture of ketones, aldehydes, and other compounds. Caramelization may begin at temperatures lower than 100 degrees C. (212 degrees F.) when moisture is present. An alkaline reaction accelerates the process. Glucose and fructose are especially subject to caramelization; consequently, when honey is used in a cooked mixture it may be necessary to add acid to preserve the original flavor or prevent overcaramelization.

The loss of water and of other volatile decomposition products during caramelization leaves a product of less weight than that of the original sugar. Caramel is noncrystallizable and less sweet than sucrose, though no exact measurements have been made and the sweetness varies with different samples.

THE PREPARATION OF FOOD MIXTURES HIGH IN SUGAR

The general increase in sugar consumption is especially remarkable because it is not a result of eating of more sugar directly so much as it is due to its use as a flavoring or for other purposes in food mixtures. The foods in which sugar is an important component may be grouped as follows: (1) candies and cake frostings

12 Willaman et al., *Am. J. Physiol.*, 73: 397 (1925).

(confections); (2) flour mixtures, especially cakes and cookies (see Chapter 15); (3) frozen mixtures (see Chapter 10); (4) jams and jellies; (5) beverages.

Candies and Cake Frostings

Candies and frostings are food mixtures containing essentially sugars and flavoring materials. The principles of their preparation are similar, and for convenience the following discussion will treat more specifically of candy making. By properly chosen variations in ingredients and in their treatment, these mixtures may result in either crystalline or amorphous products.

Crystalline Candies

"An impalpably smooth fondant of rather fluid consistency" has been called the highest example of the candy maker's art. Because fondant is the simplest crystalline candy from the standpoint of ingredients, probably the most important one commercially, and the one on which most research has been carried out, it has been chosen to typify this group.

Briefly stated, the process of making fondant consists of solution of the sugar in water, concentration of the solution so that it becomes highly supersaturated at room temperature, and recrystallization to form huge numbers of very small crystals in this supersaturated solution. Thus there are four essential steps: (1) securing complete solution; (2) securing the proper degree of concentration; (3) securing the proper degree of supersaturation; (4) securing the desired type of crystallization.

The factors of importance in each of these operations will be discussed in turn.

1. Securing Complete Solution. The highest degree of supersaturation is reached in solutions which contain no nuclei to stimulate early crystallization. Undissolved crystals, or even particles of dust, may serve as such nuclei. Molecules of sucrose tend to attach themselves to these particles when supersaturation is reached, rather than to each other, with the formation of nuclei. Thus a few large crystals instead of many small ones result. Consequently, it is important that every crystal of sucrose be dissolved in the first stage of preparation of fondant. Complete solution is promoted by the addition of excess water, by fine division of the solute, by stirring,

and by heating. Heating increases the solubility of the sucrose in water, as indicated in Table XLVIII.* Permitting the pan to

Table XLVIII. Solubility of sucrose in water at different temperatures

[After Browne]

Temperature		Grams sucrose in 100 grams solution	Grams sucrose dissolved by 100 grams water
Degrees C.	Degrees F.		
0	32.0	64.18	179.2
5	41.0	64.87	184.7
10	50.0	65.58	190.5
15	59.0	66.30	197.0
20	68.0	67.09	203.9
25	77.0	67.98	211.4
30	86.0	68.70	219.5
35	95.0	69.55	228.4
40	104.0	70.42	238.1
45	113.0	71.32	248.7
50	122.0	72.25	260.4
55	131.0	73.20	273.1
60	140.0	74.18	287.3
65	149.0	75.18	302.9
70	158.0	76.22	320.5
75	167.0	77.27	339.9
80	176.0	78.36	362.1
85	185.0	79.46	386.8
90	194.0	80.61	415.7
95	203.0	81.77	448.6
100	212.0	82.97	487.2

remain covered until boiling has proceeded for 3 or 4 minutes causes the vapor to condense and wash down any crystals that might have adhered to the sides of the pan. The pan should then be uncovered to allow evaporation to proceed unhindered.

2. Securing the Proper Degree of Concentration. In order to recrystallize the sugar, it is necessary to concentrate the solution so that under appropriate conditions it will become supersaturated. Concentration is obtained by continuing boiling until the proper amount of evaporation has occurred. Temperature is a measure of the extent of concentration, because the boiling point of sucrose solutions rises as the concentration of the solution increases. The boiling points of sucrose solutions of different concentrations are

* Browne, *A Handbook of Sugar Analysis*, John Wiley & Sons, 1912, p. 649 (out of print).

Table XLIX. The boiling points of sucrose solutions of different concentrations

[After Browne]

	Per cent Sucrose								
	10	20	30	40	50	60	70	80	90.8
Boiling point									
Degrees C.	100.4	100.6	101.0	101.5	102.0	103.0	106.5	112.0	130.0
Degrees F.	212.7	213.1	213.8	214.7	215.6	217.4	223.7	233.6	266.0

given in Table XLIX. These data lose some of their practical significance, however, when it is recognized that they apply to solutions of pure sucrose only. In candy making it is customary to add a portion of glucose, or to invert part of the sucrose, for reasons connected with crystal formation that will be discussed later. When sucrose is inverted, the two molecules of monosaccharide formed from each single molecule of the original dissacharide cause the boiling point to rise more rapidly in relation to concentration of sugar. Also, a given concentration of glucose when cooled will become supersaturated at a lower temperature than the same concentration of sucrose. Consequently, it is necessary to know the correct final temperature for a particular recipe. Even this may vary, because the amount of inversion depends upon the time of heating as well as upon the amount of inverting agent. A household check on the thermometer test is the degree of hardness reached by a small sample of the solution when added to cold water. When fondant is "done," it forms a soft ball under these conditions. Extreme concentration causes the sample to form a harder ball. A thermometer test for fondant solutions, which is approximately correct, is cooking to a temperature 15 degrees C. (27 degrees F.) above the local boiling point at the time.* (See Table L.)

3. Securing the Proper Degree of Supersaturation. A sugar solution boiling at 234 degrees F. (112.22 degrees C.) contains 80 per cent sucrose, or 80 grams of sucrose and 20 grams of water in 100 grams of solution. (See Table XLIX.) The solubility of the sugar in this concentration indicates that supersaturation develops when the temperature is lowered to 194 degrees F. (90 degrees C.). (See Table XLVIII.) If the cooling is gradual and if all other precautions which tend to prevent crystal formation have been observed, supersaturation increases as the temperature decreases.

* Halliday and Noble, *Hows and Whys of Cooking*, 3rd edition, University of Chicago Press, Chicago, 1946, p. 205.

Table L. Temperatures and tests for sirup and candies

[From *Handbook of Food Preparation*, by permission of American Home Economics Association]

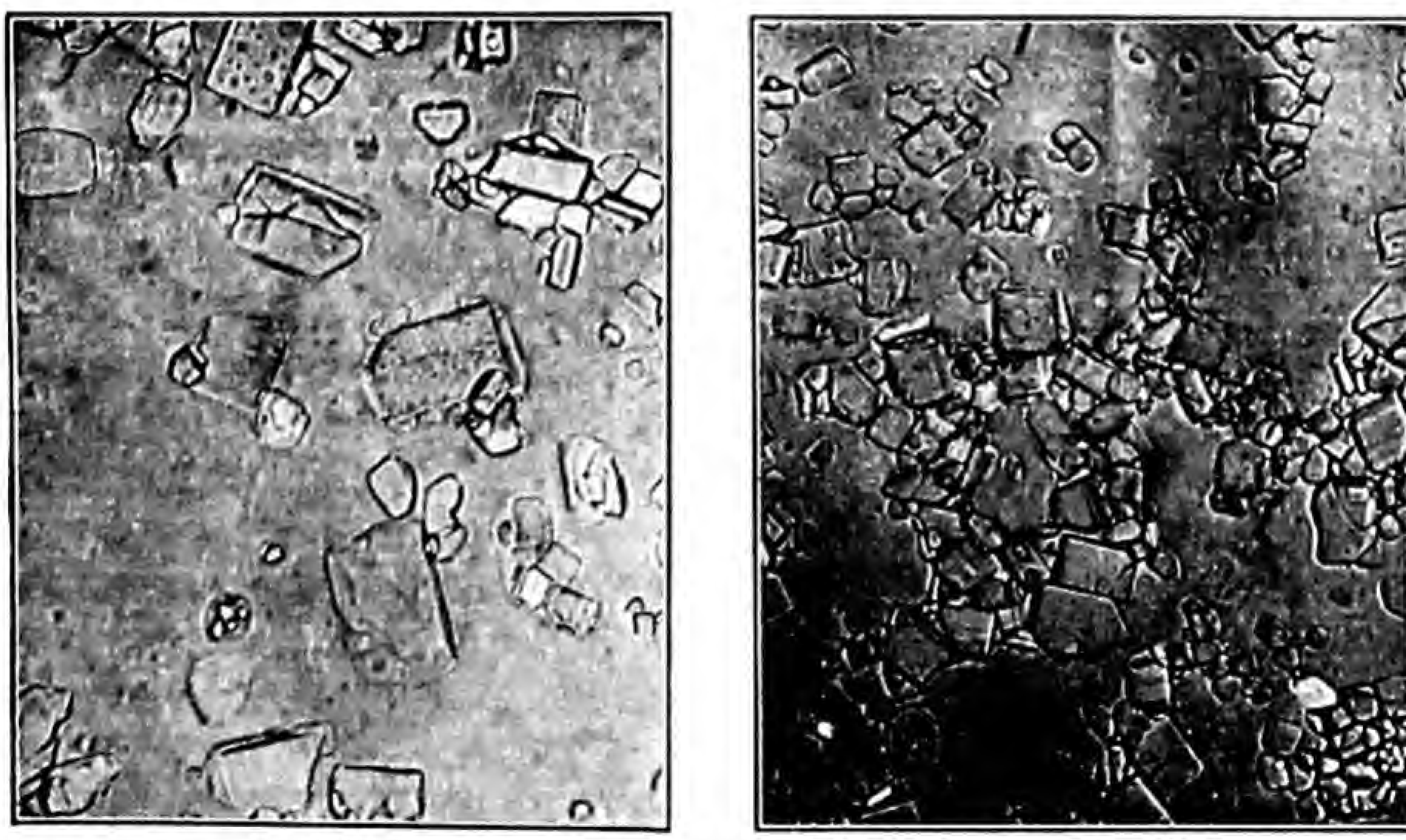
Product	Temperature of sirup at sea level (indicating concentration desired) Degrees F.	Degrees C.	Stage of concentration desired	Behavior at stage desired
Sirup	230 to 234	110 to 112	Thread	The sirup spins a two-inch thread when dropped from fork or spoon.
Fondant, Fudge, Penuche	234 to 240	112 to 115	Soft ball	The sirup when dropped into very cold water forms a soft ball which flattens on removal.
Caramels	244 to 248	118 to 120	Firm ball	The sirup when dropped into very cold water forms a firm ball which does not flatten on removal.
Divinity, Marshmallows, Nougat, Popcorn balls, Salt-water taffy	250 to 266	121 to 130	Hard ball	The sirup when dropped into very cold water forms a ball which is hard enough to hold its shape yet is plastic.
Butterscotch, Taffies	270 to 290	132 to 143	Soft crack	The sirup when dropped into very cold water separates into threads which are hard but not brittle.
Brittle, Glacé	300 to 310	149 to 154	Hard crack	The sirup when dropped into very cold water separates into threads which are hard and brittle.
Barley sugar	320	160	Clear liquid	The sugar liquefies.
Caramel	338	170	Brown liquid	The liquid becomes brown.

4. Securing the Desired Type of Crystallization. When the correct degree of supersaturation has been reached, the final step in the making of crystalline candies is the production of conditions which will result in the formation of very many fine crystals with no large ones. The conditions which promote the formation of many nuclei, and consequently of small crystals, are: (*a*) absence of premature or undissolved crystals; (*b*) a high degree of supersaturation when crystallization begins; (*c*) extensive agitation as soon as the proper degree of supersaturation is reached; (*d*) the presence of substances which interfere with the rate at which crystals form.

(*a*) *Absence of premature or undissolved crystals.* The preliminary solution in excess water and heating to increase solubility

are employed to destroy the original crystal structure of the sugar. In addition, it is important that there be no spattering on the sides of the pan, no formation of air bubbles in the fondant when it is poured on the cooling surface, and no addition of scrapings from the pan when it is emptied. These may lead to the formation of new crystals which serve as nuclei for premature crystallization. As already mentioned, it is said that even dust particles from the air may cause premature crystallization and consequent coarseness in the product.

(*b*) *A high degree of supersaturation when crystallization begins.* A high degree of supersaturation before crystallization begins is desirable because it promotes the production of many nuclei simultaneously. It has been found that agitation at 104 degrees F. (40 degrees C.) is optimum for crystallization in fondant.[13] Stimulation of crystal formation at higher temperatures tends to result in fewer, larger crystals, whereas delay until lower temperatures are reached increases the time of beating, on account of the increased viscosity, without significant compensating improvement in quality. (See Fig. 39.)



(*a*) (*b*)

FIG. 39. Photomicrographs showing the effect of temperature of beating on size of crystals in fondant made with no acid or glucose. × 360. (*a*) Sirup beaten while hot (70° C.), coarse textured; (*b*) sirup beaten cold (40° C.), finer textured. (*Courtesy Sibyl Woodruff.*)

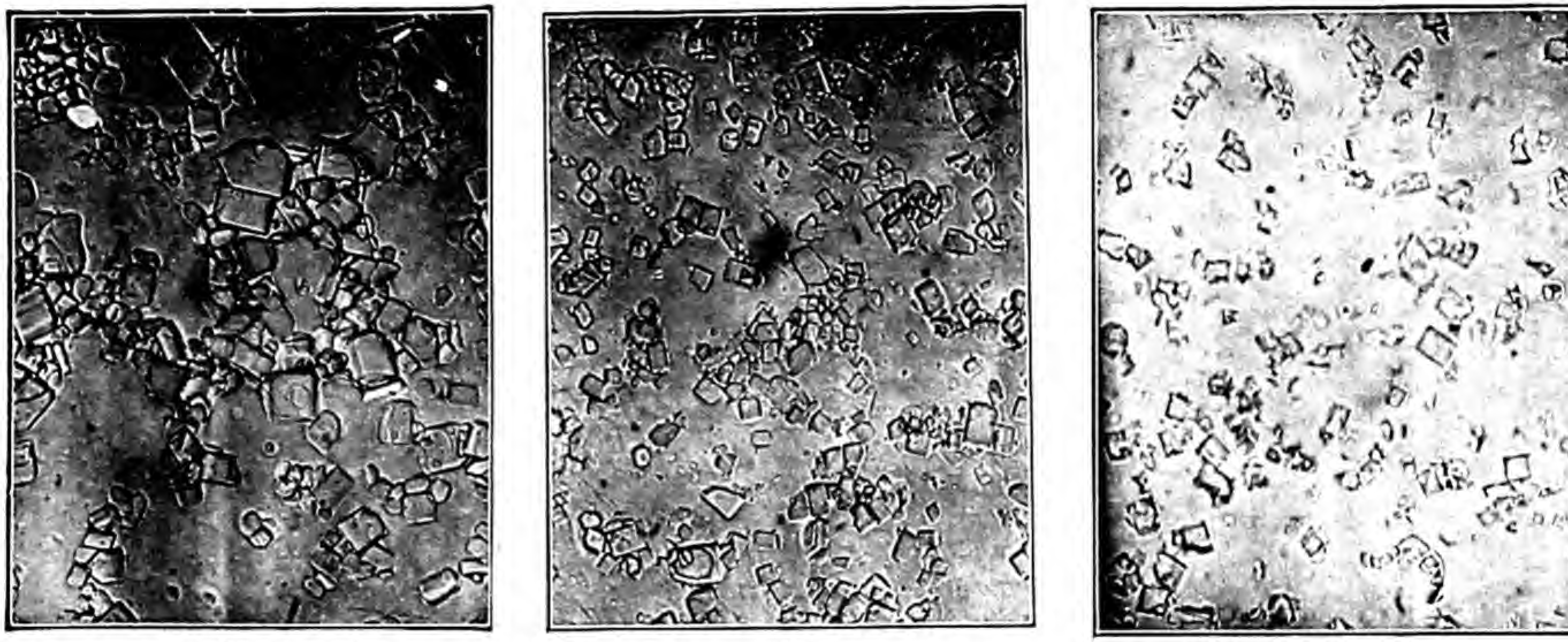
[13] Carrick, *J. Phys. Chem.*, 23: 589 (1919).

(*c*) *Extensive agitation as soon as the proper degree of supersaturation is reached.* When a fondant mixture is not disturbed during cooling, crystallization will finally occur spontaneously. Crystals so formed, however, are coarse because few nuclei form at the beginning and the sugar molecules attach themselves to these instead of starting new ones. Agitation of supersaturated solutions tends to cause the formation of many nuclei simultaneously. Rapid beating of crystalline candy mixtures of the proper degree of supersaturation produces the most palatable structure. This stage is apparent as a sudden softening which is followed by a stiffening. The softening is caused by the heat of crystallization (the same as the latent heat of freezing), and the stiffening results when this source of heat fails.

(*d*) *The presence of substances which interfere with crystal formation and growth.* The clustering of the sugar molecules to form crystals is hindered by the presence of substances which do not crystallize easily or which increase viscosity and consequently decrease molecular movement. Under such conditions the tendency is towards the formation of many nuclei and small crystals. (See Fig. 40.) In candy making, the principal substances employed for this purpose are sugars which are less easily crystallized than sucrose, especially dextrose (in the presence of other sugars), and invert sugar. Dextrose in the form of commercial glucose or corn sirup is often used because it is cheap, but both dextrose and fructose may be made from the sucrose in the candy mixture by the addition of an inverting agent. Probably the fat added in some candy mixtures in chocolate, butter, cream, etc., also interferes mechanically with crystal growth.

In the household, it is customary to add a small amount of acid to fondant and similar candy mixtures to invert part of the sucrose. Not only do the dextrose (in mixtures) and fructose crystallize with much less speed than sucrose and thus interfere with its crystallization, but they also increase the solubility of the sucrose from 67 to about 80 per cent at room temperatures. Moreover, dextrose crystals, if formed, are very fine. Cream of tartar, citric acid, lemon juice, and vinegar are commonly used as inverting agents. Cream of tartar is readily available, constant in acid content, easily measured, and consequently preferable to the others.

The amount of invert sugar formed depends upon the kind and concentration of the acid and the time and temperature of heating. When the amount of acid in fondant mixtures was varied and they



(*a*) (*b*) (*c*)

FIG. 40. Photomicrographs showing the effect of additions of glucose and K H tartrate on crystal size in fondant (all beaten at 40 degrees C.). (*a*) No addition of acid or reducing sugar (contained 0.42 per cent reducing sugar; (*b*) added glucose (contained 7.46 per cent reducing sugar); (*c*) added K H tartrate (contained 6.46 per cent reducing sugar). (*Courtesy Sibyl Woodruff.*)

were uniformly heated, the amount of invert sugar formed varied as is shown in Table LI.[13a] It is difficult to control inversion under

Table LI. Invert sugar in fondant made with varying amounts of acid and constant amounts of sucrose (110 grams) and water (110 cc.)

[After Daniels and Cook]

Cream of tartar, grams	Invert sugar, %
0.12	1.26
0.18	3.29
0.24	4.34
0.60	8.46
1.20	16.85

household conditions because it is affected by the alkalinity of the water used, the speed of heating, and the amount of water to be evaporated. One experimenter found that more than 1/8 teaspoon of cream of tartar per cup of sugar gave a product acid to the taste and sticky, because it contained too much invert sugar.[14] The production of about 6 per cent of invert sugar was thought to give optimum flavor and texture.

In another investigation, it was likewise found that about 6 per cent of invert sugar was sufficient to produce small crystals in fondant but that any amount up to 15.8 per cent was satisfactory.[15] Dextrose, fructose, and invert sugar were used with equal success, but it was not easy to control inversion by acid, especially when citric or tartaric acids were used. Candy of agreeably fine texture contained no crystals measuring more than about 19 microns long, whereas some coarse samples contained crystals 45 microns in length. For practical household use Stanley and Cline recommend 1/8 teaspoon of cream of tartar to 1 pound of sugar, the amount of the former to be increased in hard waters.

In commercial candy making, glucose or invert sugar is added directly, or inversion is brought about by adding invertase to the candy. The amount of inversion produced by invertase depends upon the quantity of the enzyme added, the conditions of holding, especially the temperature, and the hydrogen-ion concentration of

[13a] Daniels and Cook, *J. Home Econ.*, 11: 65 (1919).

[14] Carrick, *J. Phys. Chem.*, 23: 589 (1919).

[15] Woodruff and Van Gilder, *J. Phys. Chem.*, 35: 1355 (1931).

the candy. By using this method, inversion may be allowed to proceed until the fondant centers dipped with chocolate become very fluid, and it is possible to make candies months in advance of their sale and yet have their quality under control.

The most complete control of crystal formation in fondant is secured by adding a definite amount of dextrose before concentration is complete. In the household, corn sirup, molasses, or honey is the source usually employed. Halliday and Noble report that inversion by acid gives a slightly superior consistency to the product as compared with adding corn sirup. Perhaps the dextrins in the corn sirup have a tendency to develop the stickiness sometimes noted when it is used. If a candy mixture fails to crystallize after prolonged beating, it may be treated as invert sugar and added in small proportions to new mixtures.

When crystallized, fondant assumes an apparently solid consistency, but on standing overnight it may become sticky. This can be explained by the nature of its structure. The fondant mass is composed of a mother sirup in which many minute crystals are suspended. The equilibrium between crystals and sirups is constantly shifting, especially with changes in temperature. When the fondant softens or "ripens" overnight, it has been suggested that the smaller, cementing crystals, which have been deposited between the larger ones and hinder their movement past each other, dissolve, and thus movement is permitted. It is a common experience that kneading at this stage produces some stiffening, which may be a result of recrystallization or of further evening up of the texture. Crystals in fondant which contains invert sugar do not increase in size over a period of 3 weeks at least. Softening after standing may be controlled by losses and gains of water to and from the air, for candies containing invert sugar are hygroscopic.

Amorphous or Noncrystalline Candies

Perfect amorphous candies do not contain crystals, nor do crystals form in them on standing. They include brittles, hard candies such as taffy and butterscotch, and caramels. As in the preparation of crystalline candies, complete solution must be the first step. Evaporation and concentration are carried further than in solutions for crystalline candies, so that the high viscosity and rapidity of solidification on cooling do not allow time for pattern formation by the

molecules of sugar. Crystal formation is further hindered by the inclusion of larger amounts of inverting agents, or dextrose, and fat. Some amorphous candies tend to crystallize on standing.

The Appraisal of Candies as Food

By 1935, the manufacture of candy had achieved eighth place among food industries in the United States in the value of its products and was supplying 16 pounds per capita. Half of this weight is sugar. The remainder includes nuts, gelatin, fruits, milk, butter, coconut, corn sirup, molasses, and miscellaneous materials. The nutritive quality varies, of course, with the particular ingredients employed, but candy must in general be classed as an unbalanced food carrying only insignificant amounts of vitamins and usually very low proportions of protein and essential minerals. (See Table LII.) Certainly the amounts eaten by many people are not adequately balanced by the remaining foods that they consume. Its effect in dulling the appetite makes it an important factor in much undernutrition of children, and its addition to diets already adequate if not excessive in calories contributes to many cases of overweight.

The role of candy in relation to dental decay is still controversial, but, as is the case with sugar and sugar-rich foods in general, restricted consumption of candy by children has been found to be correlated with a lower than average amount of decay. Hard candies of the type held in the mouth for long periods are frequently so highly acidified that they may have a direct destructive action on tooth enamel.

Although there has been considerable pressure on the part of those commercially interested to obtain authoritative approval of the fortification of sugar and candy with vitamins, neither the Council on Foods of the American Medical Association nor the Committee on Nutrition of the National Research Council has conceded its support. Such fortification would not conform to the general principle that this practice should be restricted primarily to replacement of constituents originally present but lost during processing.

Contemporary advertisers have been exploiting the value of sweets in a way that is distinctly misleading and especially insidious, be-

[16] West and Judy, *J. Dental Research*, 17: 499 (1939). Current Comment, *J. Am. Med. Assoc.*, 112: 2606 (1939).

Table LII. The nutritive contributions of candies, given as percentages of the *Recommended Allowances* for a physically active man

[Babcock, *N. J. Agr. Expt. Sta. Bull.* 751 (1950)]

		Food nutrients								
Kind of candy	Amount	Energy	Protein	Calcium	Iron	Vitamin A	Thia-mine	Ribo-flavin	Niacin	Ascorbic acid
Butterscotch	1 oz.	4	0	½	4	(0) *	(0)	(0)	(0)	(0)
Caramels	1 oz.	4	1	3½	6	1	½	2	0	(0)
Chocolate, milk with almonds	1 oz.	5	3½	6	6½	1	2½	8	(2)	(0)
Chocolate creams	1 oz.	3½	1½	...	...	...	...	...	...	(0)
Fondant	1 oz.	3½	0	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Fudge	1 oz.	4	½	1	1	1	(0)	1	(0)	(0)
Marshmallows	1 oz.	3	1½	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Peanut brittle	1 oz.	4	3½	1	5	0	2	½	9½	(0)

* Imputed figures in parentheses.

cause it is directed to the feeding of children. Statements are made that the high-calorie requirements of the young can be met efficiently by such foods, but mention is not made of the very high protein, vitamin, and mineral needs of this age group. The Council on Foods of the American Medical Association has considered the claims of candy advertisers and concluded that "recommendations for the use of candy by young children can only be detrimental to their proper nutrition." [17] Very palatable and at the same time highly nutritious sweetmeats incorporating cheese, dry milk, peanut butter, and brewer's yeast have been developed experimentally and others could well be devised for household preparation.[18] Our military services have also developed candy bars containing concentrated milk products, brewer's yeast, and soya protein to serve as highly nutritious and palatable emergency rations or as supplements to regular rations. The mixing of sugar with highly nutritious natural foods in this way rather than fortifying it with a few synthetic vitamins is to be encouraged as a safer procedure.

The evidence on the digestibility of sugar applies largely to candies. Under existing legislation, commercial candies are probably almost always composed of wholesome ingredients. The inclusion of non-food substances, such as metallic prizes, is now forbidden because of the hazard involved. Although candy appears to have a relatively clear record so far as disease transmission is concerned, contaminated nuts, raisins, and other ingredients may be responsible for the presence of undesirable kinds of bacteria in the finished product. Sanitation of factories is not always subject to governmental supervision, and the conditions of holding and handling in retail stores may be extremely unsanitary.[19]

The economy of candy as a food depends upon the price that is paid for it. Cheap candies, like the sugar which is their principal ingredient, are fairly inexpensive sources of energy.

Jellies, Jams, and Preserves

Jellies and other concentrated fruit products high in sugar are combinations of fruit juices or juices and pulp with such a large proportion of sugar that they are essentially sweets in dietary roles.

[17] Council on Foods, *J. Am. Med. Assoc.*, 128: 204 (1945).

[18] Spinella, *J. Am. Dietet. Assoc.*, 21: 84 (1945).

[19] Tanner and Snyder, *Proc. Inst. Food Technol.*, 307 (1940).

Their preparation is based on the gel-making power of the pectin in the natural product or of added pectins. Enough sugar is added to give an amount in the finished product which is sufficient to prohibit bacterial growth and accompanying spoilage. Preserves are products containing whole or cut fruits. Jams are made with crushed or mascerated fruit. Jellies include fruit juices only. Jelly making will be discussed in some detail but the principles of preparing the other products in this group are the same.

The Composition and Structure of Fruit Jellies

Perfect fruit jellies have a clear color and a flavor characteristic of the fruit, are transparent and sparkling, quiver but do not flow when removed from their molds, are tender enough to cut easily, and are so firm that angles thus produced retain their shape. Fruit juices contain flavorings, minerals, sugar, plant acids, and pectins. Successful jelly formation requires proper proportions of sugar, acid, and pectin. The process may be described briefly as a gelation of pectin which takes place over a limited range of acidity.

According to modern conceptions, the pectins in the sol state are negatively charged, highly hydrophilic colloids. As in other dispersions of this type, gelation results from a partial precipitation with the formation of a network which holds the remaining constituents within its meshes. Easily broken jellies probably contain short, or weakly bonded, threads in the brush-heap structure. Sugar diminishes stability by dehydrating the pectin particles, and the hydrogen ions by reducing their charge. Time is required for the dehydration of the pectin particles by sugar, and the rate is accelerated directly as the hydrogen-ion concentration is increased. When the sugar-pectin solution reaches equilibrium, its jelly strength is at a maximum. What the particular maximum will be depends upon relationships among the water, sugar, and pectin at this point and is controlled by the proportions of sugar, pectin, acid, and salts, and by the temperature. It has been said that each combination has a time limit; that is, there comes a time at which the jelly structure is so strongly formed that its final state is altered by any mechanical disturbance, such as pouring, occurring at that juncture.

Because a surplus of water makes pectin extraction more efficient, most fruit extracts require concentration by evaporation to obtain a sufficient proportion of pectin for gelation. Sugar is always added to increase tenderness and yield and to improve flavor, but some

fruits containing sufficient pectin for jelly making lack the degree of acidity required to produce gelation. Fruits containing both sufficient acid and pectin include sour apples, sour blackberries, cranberries, red currants, gooseberries, Eastern and wild grapes, sour guava, lemons, loganberries, sour oranges, most varieties of plums, and black and red raspberries. Unripe figs, bananas, pears, sweet apples, some varieties of ripe quinces, and sweet prunes are rich in pectin but deficient in acid. Pomegranates, strawberries, European grapes, and ripe apricots are rich in acid but deficient in pectin. Peaches, ripe figs, and other overripe fruits are deficient in both acid and pectin. (See Table LIII for proportions of water and sugar to use with different fruits.)

Table LIII. Proportions of water to fruit, and of sugar to fruit juice in making jellies *

Kind of fruit	Quantity of water to each pound of prepared fruit (for extraction of juice), cup	Time of boiling fruit to extract juice, minutes	Quantity of sugar to each cup of fruit juice, cup
Apples †	1	20 to 25	¾
Crab apples ‡	1	20 to 25	1
Blackberries	Firm fruit, ¼	5 to 10	¾ to 1
	Very soft fruit, none	5 to 10	¾ to 1
Black raspberries	Very soft fruit, none	5 to 10	1
Cranberries	3	5 to 10	¾
Currants	¼ or none	5 to 10	1
Gooseberries	¼	5 to 10	1
Grapes such as Concord §	¼ or none	5 to 10	¾ to 1
Grapes, wild	1	5 to 10	1
Plums, Wild Goose type	½	15 to 20	¾
Quinces	2	20 to 25	¾
Red raspberries	None	5 to 10	1

* Yeatman and Stienbarger, *U. S. Dept. Agr., Farmers' Bull.* 1800.

† To make mint-flavored apple jelly, after the jelly stage is reached and just before the sirup is ready to pour into the glasses, tint with green food coloring and add a few drops of essence of spearmint or peppermint.

‡ For spiced crab apple jelly, cook with the sugar and the juice from 8 pounds of fruit, four 2-inch pieces stick cinnamon, and 12 whole cloves tied loosely in a cheesecloth bag.

§ For spiced grape jelly, cook 6 pounds of Concord grapes with 1 cup of vinegar, 1 tablespoon of cloves, and 5 pieces of 1-inch stick cinnamon. Strain. Proceed with juice as for grape jelly.

Pectin and Jelly Formation. Protopectin has been discussed as a component of the cement between plant cell walls and of the cell walls themselves. It is most abundant during the immature stage in fruits and is converted to pectin by an enzyme as maturity develops. When fruit is heated, the protopectin remaining is partially hydrolyzed to pectin, and this pectin, together with that already formed, is dissolved. In most cases very little pectin is present in the original fruit juice; hence juices expressed cold will not usually form jellies. Frequently the amount of pectin extracted can be increased by adding to the acid content of the extraction solution.

When fruit is very ripe, another enzyme breaks up pectin into pectic acid and alcohol. Pectic acid does not form a gel except in the presence of added calcium ions; hence overripe fruit has poor jelly-making properties. Long boiling of juice also promotes this decomposition and may be the cause of jelly failure. Pectin solutions of maximum strength are secured by a period of about 30 minutes' boiling. The division of this period into two 15-minute extractions has been recommended for best results with apples.

Commercial pectins are concentrates of the pectin from cull apples and waste peels and cores at canneries and from cull lemons. They are marketed as sirups or powders and used to make artificially flavored products or to supplement the pectin content of fruit juices. They have no pronounced flavor of their own. Liquid commercial pectins tend to deteriorate after being opened, and consequently they should be used promptly.

The jelly strength of pectins is related to their viscosity.[20] Pectins from different sources vary in their jelly-making strength and also in the quality of the jellies produced. For example, citrus pectin jellies are comparatively friable and inelastic; those made from apple pectin are highly elastic and less tolerant of acid in excess. The difficulty in making a satisfactory jelly from cranberries has been attributed to the too rapid setting of the natural pectin. For commercial use, a recommended procedure includes decomposing the original pectin by the appropriate enzyme and supplanting it with a more suitable type. Commercial pectins should be sold on the basis of jelly strength as determined by tests. Pectin concentrates may also be made in the household from citrus peel or cull apples.

[20] Bennison and Norris, *Biochem. J.*, 33: 1443 (1939).

The use of pectin concentrates greatly increases the number of fruits available for jelly making. Because the pectin content of fruit reaches a maximum before the fruit is fully ripened, the time when color and flavor are at their height, it is sometimes preferable to use ripe fruit for jelly making and supplement its pectin content. The use of supplementary pectin also decreases the amount of boiling necessary for evaporation, thus diminishing injury to delicate flavors. In some cases, however, the concentration of flavor resulting from evaporation gives a superior product.

When jellies made with and without a commercial pectin supplement are compared, those made with the additional pectin are bright and more transparent with no lessening of color except in crab apple. The natural juice flavor may be less if pectin is added. Jellies made with a pectin concentrate may cost less than those made from unsupplemented juices. The citrus fruits contain so much pectin of their own that there is no advantage in adding the concentrated forms to orange and lemon marmalades.

The amount of pectin in a finished fruit jelly averages from 0.5 to 1.0 per cent, but commercial jellies may have a little more to increase their stiffness and hence make them withstand shipping better.

Because the amount of sugar which should be added depends upon the pectin content of the extract, it is desirable to make an approximate pectin determination unless the proportion of water has been standardized as in Table LIII. The most popular of the household methods has been the alcohol test, which consists of adding one spoonful of the extract to about three spoonfuls of alcohol (denatured may be used if not tasted). If the extract is rich in pectin, a firm, jellylike mass will form. This is evidence that ¾ to 1 cup of sugar may be added to 1 cup of extract. If the pectin precipitates in the form of several lumps, the extract is medium in content of this component and requires more evaporation to secure sufficient concentration; ½ to ⅔ cup of sugar is a proper proportion for addition to 1 cup of such extract. When the pectin concentration is less than this, as indicated by the precipitation of a few small stringy lumps, the extract should be concentrated and then tested before the proportion of sugar to be added is estimated.

The principal cause of failure in jelly making is the addition of too much sugar. It is very difficult to determine optimum proportions by simple household tests. The alcohol test is not an accurate measure of jellying power because that property is not solely a question of the amount of pectin present, but also of its quality and of

other conditions which affect gel formation, such as acidity. Furthermore, alcoholic precipitates in fruit extracts contain other substances beside pectin.

Viscosity of the juice is influenced mainly by the pectin concentration, and hence can be used to measure pectin and to estimate the appropriate proportion of sugar. A pipette has been devised for determining relative viscosity, and a table has been worked out which gives the amount of sugar suitable for a unit of juice of each viscosity.[21] The concentration end point for the mixture has also been determined in terms of final weight. The inventor says that this procedure is satisfactory when the hydrogen-ion concentration of the juice is about *p*H 3. These pipettes can be purchased at a small cost.* If household jelly making is to become anything but a process doomed to frequent failures, some such procedure to increase its exactness must be adopted.

Acid and Jelly Formation. According to the theory of jelly formation mentioned previously, for any pectin-sugar combination under given conditions of temperature there is a maximum hydrogen-ion concentration which just permits the completion of gelation (the reaching of an equilibrium between sugar and pectin with the attendant partial precipitation of the pectin) within the time limit of the system. It will be remembered that the time limit of the system is the point at which mechanical disturbance, such as pouring, will reduce the perfection and strength of the gel structure. Such a maximum hydrogen-ion concentration represents optimum acidity for the mixture. When the sugar concentration is low, the time of setting is so slow that an "optimum" hydrogen-ion concentration does not appear. Thus in an experiment with a 50 per cent sugar concentration, strength increased continuously although the *p*H was dropped to 1.05, whereas a jelly of 60 per cent concentration of sugar had a maximum jelly strength at *p*H 3.06 and one of 70 per cent at *p*H 3.35.

The acid concentration affects the final structure through alteration of the rate of setting, but, as just explained, it does not show an optimum when the setting time is made sufficiently long by diminishing the sugar content. Given a certain proportion of a particular pectin, the sugar and acidity control the strength of the jelly, the sugar by dehydration of the pectin micelles and the acid by its own

[21] Baker, *Food Inds.*, 7: 170 (1935).

* Sold by the Jelmeter Co., Bridgeton, N. J.

destabilizing action and its effect on the speed of the attainment of a sugar-pectin equilibrium.

Under practical jelly-making conditions, high quality in the product is associated with a sugar content of about 65 per cent and a *p*H of 3.4 to 3.1, the jelly being somewhat stiffer at the latter *p*H. If the hydrogen-ion concentration is increased, syneresis is likely to occur. The hydrogen-ion concentration of natural fruit juices is conditioned by the kind and quantity of acids present and the buffer action of the juice. The latter depends upon its mineral salt content. The mineral salts also exercise other more or less important effects on gelation, probably through differential adsorption of the ions by the pectin micelles.

When fruit extracts are deficient in acid, either characteristically or because they are from overripe fruits, it is possible to improve their jellying by the addition of acid such as citric or tartaric, by the inclusion of lemon juice, or by blending with other fruit juices which are sour. It is difficult to measure acidity with household equipment, but it has been suggested that a rough test can be made by comparing the sourness of the fruit extract in question with that of a mixture of 1 teaspoonful of lemon juice and 8 teaspoonfuls of water. The fruit juice should be at least as sour as this solution.

Sugar and Jelly Formation. It is possible to prepare a kind of jelly without augmenting the natural sugar content of fruit juices, but the product is tough and unpalatable. The addition of sugar is essential to secure ideal texture, appearance, flavor, and yield.

The amount of sugar in finished jellies varies considerably, but there tends to be an ideal amount for specific acid-pectin combinations within practical ranges. From 60 to 65 per cent sugar is usually preferable, according to studies of apple pectin jellies. A lower percentage of sugar gives a lower jelly strength at all hydrogen-ion concentrations and requires addition of acid to produce highest jelly strength. This is in conformity with the theory that both acid and sugar function by lowering the solubility of the pectin. Although the pectin and acid can be increased and the sugar decreased somewhat to offset this, this is not a desirable procedure because fruit jellies of low sugar, high acid, and high pectin content do not possess superior texture and flavor.

Sucrose is soluble in water at 20 degrees C. (68 degrees F.) to the extent of 67 grams in 100 grams of solution. During jelly making there is considerable inversion of sucrose as a result of the combined

action of the heat and the acid. This increases the solubility of the sucrose and explains the somewhat higher concentration of sugar that may be found in jellies giving no evidence of crystal formation. Inversion is desirable because it lowers the concentration of sucrose and diminishes the chance of crystallization, but if it is carried too far the relatively insoluble glucose may crystallize. Consequently, it is often recommended that only a moderate amount (about 40 per cent) of the sucrose be inverted by withholding it until the last half of the boiling-down process, but this is unnecessary in relatively concentrated extracts. Rapid boiling, which accelerates concentration, also limits hydrolysis.

Whether beet or cane sugar is used is not a factor in the success of jelly making because both are practically pure sucrose. Only limited proportions of corn sugar (Cerelose or dextrose) can be used successfully, however.[22] The BHNHE states that honey may replace sugar in a ratio up to one-half of the amount of sugar called for, measure for measure. The maximum proportion of ordinary corn sirup is given as one-fourth the amount of sugar. In both cases the jelly mixture should be cooked slightly beyond the jelly stage. Enzyme-converted corn sirup (Sweetose) can be employed up to half the amount of sugar, the regular jelly tests being made.[23]

In grape jelly, cream of tartar crystals, which are not to be confused with sugar crystals, frequently form. They may be largely prevented by holding the freshly extracted juice at 40 degrees F. for 24 hours and then filtering it to remove the precipitate.

The fact that fruit jelly is a sugar solution makes it possible to use temperature as a guide in judging "doneness." A properly proportioned jelly mixture is done when it reaches a boiling point 8 or 9 Fahrenheit degrees above that of water. This corresponds to a boiling point of 220 to 221 degrees F. (104 to 105 degrees C.) at sea level and indicates a concentration of 65 to 68 per cent sugar.

The boiling point is not uniformly an exact measure of the concentration of sugar present because it is raised relatively more by invert sugar than by sucrose. The amount of inversion in jelly depends upon the acidity and the time and temperature of heating. Consequently, it is safer to supplement the thermometer test with a spoon test, in which the end point is the stage at which the slightly

[22] Van Arsdale and Eddy, *Bureau Publication*, Teachers College, Columbia University (1933), p. 24.

[23] Tressler, *Fruit Prod. J. and Am. Food Mfr.*, 25: 165 (1946).

cooled mixture "sheets" off the spoon. At this stage, instead of falling off the spoon in individual drops, the portion of the jelly mixture which leaves the spoon last forms a single mass or sheet.

The sheeting test is also far from a reliable indicator of the quality of the finished jelly. Under experimental conditions, jellies which appear to give the same sheeting test often differ both in consistency and in the percentage of sugar which they contain. A specific gravity test, which in the case of jelly mixtures is primarily a measure of sugar concentration, is frequently used by the commercial jelly maker. In all methods using sugar concentration as a measure of doneness, it is essential that the proportion of sugar added to the extract be appropriate for the pectin concentration. If too much sugar is added, when the solution is properly concentrated there will not be sufficient pectin to form a firm gel. On the other hand, if too little sugar is added, the pectin will be overconcentrated when the sugar concentration is correct, and the jelly will be tough. Consequently, it is essential that a fairly accurate estimate of the pectin strength of the extract be made. In the absence of special testing equipment, such as the viscosity pipette referred to previously, perhaps the safest household method is to make a preliminary test of the jelly-making properties of a small portion of the fruit juice and subsequently to use the proportions found to be suitable.

The Appraisal of Jellies, Jams, and Preserves as Foods

Fruit jellies represent a certain degree of concentration of the constituents in fruit juices. They contain some vitamins and minerals, but these are so diluted by the added sugar that they are relatively unimportant, and the principal nutritive value of jelly is derived from its sugar content. Fruit jellies are thus, from a nutritive standpoint, sugar-rich foods and are subject to the limitations of such foods, being almost solely contributors of energy. Two tablespoons of cranberry jelly yield 100 calories,* and other jellies and marmalades are very similar in energy value. Cranberries, when made into jelly, lose their vitamin C potency. Orange marmalade and strawberry jam have been found to provide about 2.5 milligrams † and about 10 milligrams, respectively, in the same amount.[24] The method of making the strawberry jam was not given in the

* Three per cent of the *Recommended Allowance* for a physically active man.

† Three per cent of the *Recommended Allowance* for a physically active man.

[24] Richardson and Mayfield, *Mont. Agr. Expt. Sta. Bull.* 390 (1941).

study, but in an analysis of homemade products in which the berries and sugar were evaporated in the sun or heated after standing overnight, the amount present was only about 2.5 milligrams in this amount.[25] It is possible to make orange marmalade which contains 10 to 12 milligrams of ascorbic acid in 2 tablespoons (40 grams), but there is loss during holding at ordinary temperatures.[26]

So far as digestibility is concerned, the same considerations apply to jellies and similar products as to any concentrated sweets. They present almost no problems of sanitary quality because the concentration of sugar is sufficient to depress the growth of most organisms, and such spoilage as may occur is likely to be of a harmless fermentative type. They must be evaluated as rather expensive though attractively flavored sources of energy.

Sweet Beverages

Soft drinks are beverages which are essentially 10 per cent sugar solutions containing added flavorings. The typical 6-ounce bottle provides about 65 calories from the sugar and has no other nutritive value. Because soft drinks are largely consumed as between-meal refreshers, they are usually unrecognized as part of the total food consumption. Nutritionally they should be evaluated on the basis of the following considerations:

1. The calories consumed in this form are part of the total intake for the day and may or may not be needed.

2. Calories from these sources, as from sugar in any other form, should be balanced by surplus nutrients from other foods, which all too often is not the case. Children in particular, with their relatively high requirements for protein, minerals, and vitamins, and, in fact, all persons with energy requirements of less than 2500 calories have little room for foods furnishing calories only.

3. The money spent for soft drinks would, if spent for milk for example, go far toward eliminating characteristic shortages of calcium, riboflavin, and high-quality protein.

4. Some soft drinks, particularly the kola type, contain caffeine which is a stimulant to energy metabolism. Children naturally have relatively high rates of energy metabolism and probably should not consume artificial stimulants in any appreciable amount.

[25] Murphy, *J. Nutrition*, 21: 527 (1941).

[26] Lincoln and McCay, *Food Res.*, 10: 357 (1945).

5. Most soft drinks contain added acids as part of the flavoring, the kola type having the highest acidity. The amount of phosphoric acid (0.055 per cent) included in cola beverages has been shown to be sufficient to dissolve tooth enamel if in contact with it long enough. The combination of this acid with sugar is more destructive than either alone. In fact, experimenters have had difficulty in obtaining human subjects for studies of the effect of these drinks because their teeth so quickly become sensitive that chewing is interfered with. Holding a solution of sugar and acid of strengths similar to those in cola drinks in the mouth for half a minute five times a day is sufficient to produce this effect in only a few days.[27] Although proof of damage to human teeth and increased susceptibility to decay as a result of the amount of contact involved in consuming soft drinks is inconclusive as yet, evidence from both human and animal experiments justifies discretion in their use.[28]

Synthetic fruit-flavored soft drinks and their frozen counterparts (ices often frozen on sticks) are essentially acidified sugar solutions. Chewing gum and many kinds of cough drops contain sugar. The amount in these latter products is not significant, but it is consumed in a manner that subjects the teeth to the prolonged contact which promotes bacterial production of acids in the mouth.

SUMMARY OF POINTS TO CONSIDER IN THE SELECTION OF SUGAR AND FOODS HIGH IN SUGAR

1. Sugar furnishes calories only, and the larger the quantity consumed, the more carefully the remainder of the diet must be chosen to provide surpluses of other nutrients, if balance is to be achieved. Since relatively few people have the knowledge or the will to do this, it is safest to eat only limited amounts of sugar and foods high in added sugar.

2. Many grain products are as cheap as, or cheaper than, sugar as sources of energy and at the same time provide important amounts of other nutrients.

3. The cultivation and exploitation of children's appetites for sweets by making candy, soft drinks, and other sweets readily available in schools should be condemned. Experience shows that if milk

[27] McCay and Will, *J. Nutrition*, 39: 313 (1949).

[28] Gortner et al., *Arch. Biochem.*, 8: 405 (1945); McClure, *J. Nutrition*, 26: 251 (1943); Restarski et al., *J. Am. Dent. Assoc.*, 32: 668 (1945).

is equally available it competes successfully with other beverages. Fruit, sandwiches containing peanut butter, cheese, egg, or vegetable and chopped nut fillings are much more nutritious between-meal snacks than jelly sandwiches or other sweets.

4. The proper role of sugar is to increase the palatability of such foods as cooked fruits, or in more concentrated sweets, such as sweet desserts and candies, to provide a satisfying end to a meal. Limited quantities serve this purpose adequately when the rest of the meal is well-planned and prepared. There is some evidence that well-nourished children do not crave sweets and voluntarily limit consumption of them. Washing the teeth promptly after eating sweets has been found to curtail bacterial activity in the mouth and hence to safeguard the teeth.

5. Molasses is a recommended sweetener because it contains substantial amounts of minerals, but claims of unique health values for blackstrap are unsubstantiated. The high concentration of impurities that it carries may even be undesirable for large-scale human consumption.

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CHAPTER 15

GRAINS AND THEIR PRODUCTS

The composition and structure of grains.
The processing of grains.
Part A. Starch.
Part B. Breakfast foods and rice.
Part C. Pastes.
Part D. Flours.
Part E. General principles and practices in the selection and preparation of flour mixtures.
Part F. Preparation of typical flour mixtures.

Since the time when man developed agriculture to the point where he could cultivate the grains successfully, grains have played a major role in his food supply. Today some cereal is rated as the "staff of life" in nearly every country in the world. It has been accorded this position because it makes an outstanding contribution to the nutritional needs and appetite satisfaction of the population, and because it can be stored with relative ease throughout the year. The grains most commonly used in some form for human consumption include wheat, corn (maize), rice, oats, rye, and barley. Buckwheat and soybeans are noncereal seeds from which flours are manufactured. They are commonly used in combination with grain flours, however.

In spite of the fact that most of the human race has assigned the grains an important dietary role for centuries, it is significant to remember that from the standpoint of man's evolutionary development this was not always the case. In the hunting and herding stages of our economic development seeds were of little or no dietary importance. Even in the relatively recent period in the United States for which statistics are available, their role has been a changing one. (See Table LIV.)

The decline in consumption of grain products over the 30-year period covered in the table is almost as marked as the increase in such other foods as fruits, vegetables, and milk previously mentioned. Of course, these trends are related—in general, if we consume more of one food, we consume less of another. Grain products and

Table LIV. Approximate per capita consumption of grain products, 1918–1948

[From *U. S. Dept. Agr., Misc. Pub.* 691 (1949)]

Kind of grain products	Pounds per capita			
	1918	1928	1938	1948
Wheat	234.0	252.0	220.0	194.0
Rye	10.2	4.5	2.7	2.1
Rice	8.9	6.1	5.9	4.9
Corn *	54.8	35.8	26.5	20.3
Oats	5.2	5.7	3.8	3.4
Barley †	3.8	5.1	1.3	1.5

* Exclusive of sugar and sirup.
† Mostly consumed as malt.

potatoes have been reduced in part to make room for other foods which are preferred and which can now be afforded. This reduction is most marked at higher income levels. Probably another reason for reduced consumption of cereal products is the generally lower calorie requirement resulting from more sedentary living and improved heating of houses.

So far as dairy products and fruits and vegetables are substituted for grain products, nutritional welfare is improved. The same cannot be said for sugar or fats. In general, it is safe to say that raising the nutritive quality of modern diets to the level of the optimum as that is now defined does not require any further decrease in per capita cereal consumption. Appraisal of individual grain products will be given later, but as a group these foods provided on the average in 1948, 24.0 per cent of the energy, 24.0 per cent of the protein, 3.9 per cent of the calcium, 26.6 per cent of the iron, 0.3 per cent of the vitamin A, 30.8 per cent of the thiamine, 14.5 per cent of the riboflavin, 26.2 per cent of the niacin, and none of the ascorbic acid we consumed.[1] As will be discussed later, part of the iron, thiamine, riboflavin, and niacin have been added to compensate for milling losses.

THE COMPOSITION AND STRUCTURE OF GRAINS

The composition of grains varies considerably not only among species, as might be expected, but also within a variety and is af-

[1] *U. S. Dept. Agr., Misc. Pub.* 691 (1949).

fected in particular by climatic and soil conditions. As a group, however, their proximate composition is fairly similar, as is shown in Table LV.

Table LV. The proximate composition of whole grains and soybeans *

Grain	Percentage				
	Water	Protein	Fat	Carbo-hydrate	Ash
Barley	10.2	12.8	2.1	72.8	2.1
Buckwheat	12.0	12.4	2.4	71.6	1.6
Corn	11.0	10.0	4.3	73.4	1.3
Oats (oatmeal)	8.3	14.2	7.4	68.2	1.9
Rice	12.0	7.5	1.7	77.7	1.1
Rye	10.0	11.2	1.7	75.2	1.9
Wheat	8.7	11.7	2.0	75.8	1.8
Soybean (flour) †	7.5	43.4	7.8	12.0 ‡	5.8

* *U. S. Dept. Agr., Circ.* 549 (1940).
† From press cake.
‡ Estimated.

Carbohydrate, mainly in the form of starch, averages about 75 per cent. Sucrose is also present and small quantities of dextrins have been reported. Growing areas with moderate temperatures and high humidity, such as those along the Pacific coast, produce grains relatively high in starch content.

Although grains are often considered "starchy" foods, the protein that they contain (an average of 11 per cent by weight) is of practical significance nutritionally and, in relation to the use of various processed forms of the grains, in food preparation. Although the percentage of protein is fairly similar in all grains, the chemical composition of the protein varies considerably among different species, depending upon the amount and kind of amino acids present. Of greatest importance in food preparation are the proteins of wheat, which imbibe water to form gluten. Gluten will be discussed later in connection with flours.

Growing conditions favorably affecting the protein content of grains are in general opposite to those favoring increased starch content. For example, wheat grown in areas where hot, dry weather prevails during maturation, tends to have high protein content.

However, it has been found possible to breed a high-protein wheat which will grow in areas generally producing wheat low in protein. Also, the more nitrogen present in the soil, the higher is the protein content of the grain.

Fat is a minor component of cereal grains, and that which is present is frequently reduced in the processing to which cereals are subjected.

Cereal grains in their natural state are good sources of iron, phosphorus and the B vitamins. However, they are low in the important mineral calcium, and lack completely vitamins C and D. Only yellow corn contains provitamins A in significant amounts. Both the vitamin and mineral content vary widely with the species of the grain, the inheritance of the particular strain, and the conditions under which it is grown. As will be discussed later, processes used in making the grains more palatable for human consumption may markedly reduce both the vitamin and mineral content.

Various enzymes are present in grains which effect changes during growth and during storage and processing, both of the grains themselves and of the products made from them. Some of the more important enzymes present are the amylases and proteases which are involved in the breakdown of the starch and protein molecules, and the lipases which may be responsible for the development of rancidity in stored grains or their products. These will be discussed more in detail in later paragraphs in which their effects are applicable.

All the grains are seeds of grasses and are similar in general structure. The wheat kernel, which may be considered fairly representative of the group, consists of three well-defined regions exclusive of the outer husk. These include (1) the bran or outer layers, (2) the endosperm, which is composed of the inner floury portion, and (3) the embryo or germ, a miniature plant ready to grow when offered a favorable environment. (See Fig. 41.)

The microscope shows that the different parts of a kernel are made up of cells. These are units of protoplasm in the form of a network of protein in which the reserve food materials of the plant, starch granules, and fat globules are embedded. Each cell is surrounded by a cellulose wall of varying thickness. Though the general structure of all three of the regions defined above is similar, the proportions of the foodstuffs in each is different—the bran layers and germ containing the fat, minerals, vitamins, and most of the protein, whereas the endosperm is mainly starch.

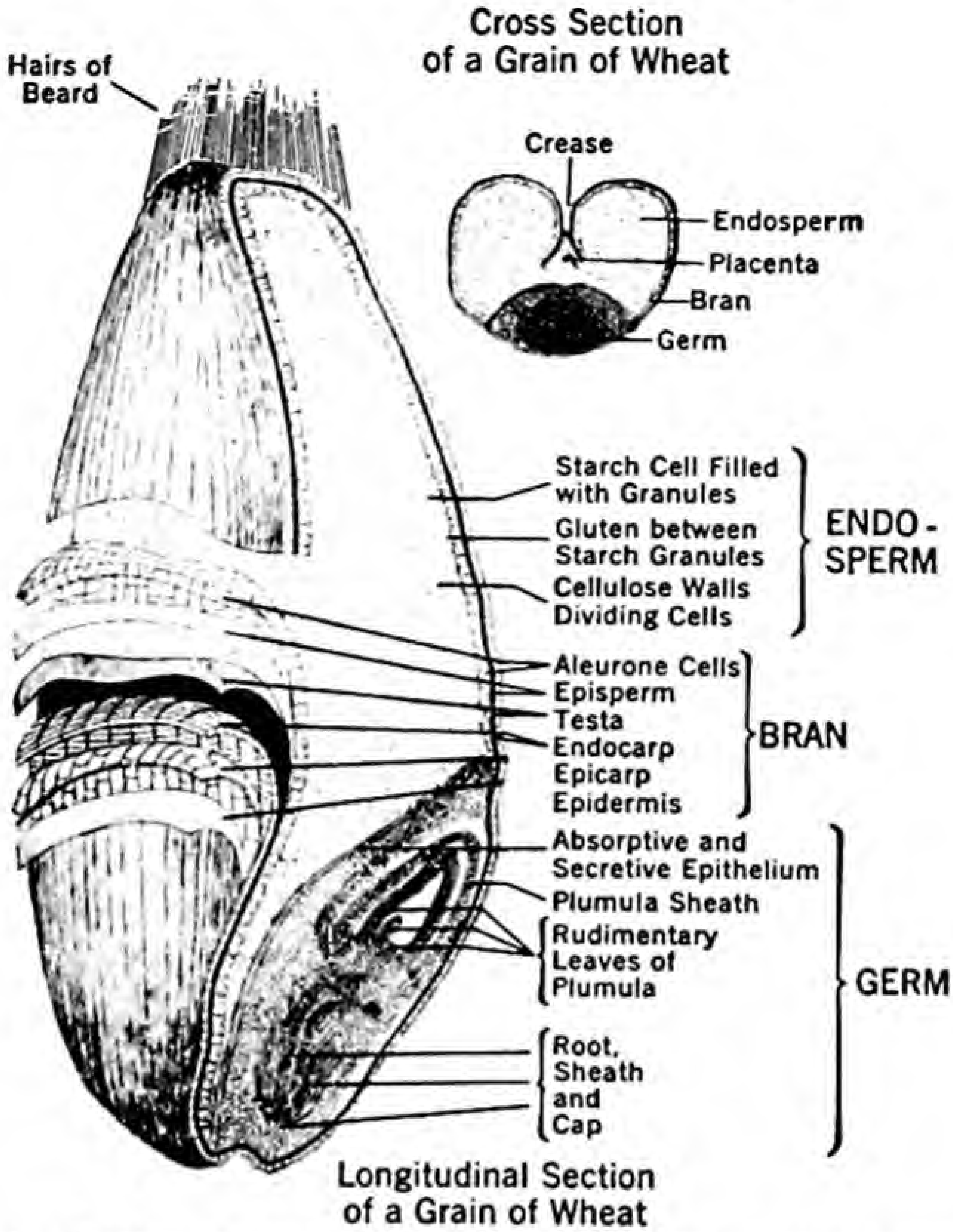

FIG. 41. Diagram of a wheat kernel. (*Courtesy Wheat Flour Institute.*)

THE PROCESSING OF GRAINS

Man finds cereals in their natural state unpalatable and universally subjects them to some form of processing including heating, subdivision, and fractionation. Because whole kernels require relatively long cooking to produce an acceptable texture, they are seldom used for food in this country. However, cleaned whole kernels of wheat may be boiled until tender and then eaten, or ground in a household food chopper and dried in an oven at low or moderate temperatures until crisp, for use in various products.

The long cooking period required to soften whole grains has resulted in their being subjected to various types of subdivision. Some of the common processes of subdivision employed include cracking, as in cracked wheat; cutting, as in steel cut oats; and grinding to varying degrees of fineness, as in producing old-process corn meals and whole wheat (graham) flour or meal.

The structural areas in the grains are so different in composition, that, in addition to subdivision, many methods of separation or fractionation have been developed and are widely used in the manufacture of the various grain products. The term "refining" is sometimes employed to cover the changes produced by fractionation.

Some of the methods employed for fractionation of cereals are:

Hulling. As in the preparation of hominy from corn, hulling takes place when caustic solutions such as lye remove the bran and loosen the embryo so that they may be separated from the endosperm. The dried whole endosperm is known as pearl hominy, the ground type as hominy grits. Corn flakes are made from grits and added flavorings. Rice is hulled as it comes from the field, leaving the product known as brown or unpolished rice. Oats have a closely adhering outer hull which is removed in the manufacture of oatmeal or rolled oats. In rice and oats, hulling is achieved by mechanical methods, and the layer removed is a husk, not an edible portion of the kernel.

Polishing. As in the preparation of polished rice, polishing is abrasion used to remove the bran and most of the embryo. Polished rice is defined as "the hulled grain from which the bran or pericarp has been removed by scouring and rubbing." Most of the embryo is removed at the same time. Before rice was polished, the husked grain (natural brown rice) was milled to remove most of the bran. Polishing represents a more complete separation of endosperm from the bran and germ.

Milling. Milling, as the term is now used, refers to the roller process used in the preparation of various wheat products. Crushing between rollers is followed by sifting (bolting) to separate fractions differing in fineness. The bran and the germ tend to be flattened by the rollers; the endosperm is pulverized. This makes separation possible. The portion of the endosperm which goes through a sieve of a specified degree of fineness is flour and that which is retained is known as middlings. After purification to remove fine bran snips, middlings may be reduced to flour by passage through additional rolls or it may be used for breakfast cereal in which case it is known as farina. Semolina, which is used for making macaroni and similar products, is the purified middlings of durum wheat, a very hard type.

Fractionation processes which separate the three major areas of grain kernels have led to the manufacture of a wide variety of products playing different culinary and nutritional roles. Table LVI

Table LVI. The proximate composition of the wheat kernel *

[After Osborne and Mendel]

	Percentage (moisture-free basis)				
Part of kernel	Protein	Fat	Ash	Fiber	Carbo-hydrate †
Whole kernel	11.25	2.18	2.03	1.75	82.97
Endosperm	11.17	1.15	0.43	0.34	86.19
Bran	17.60	8.26	8.61	11.18	54.35
Embryo	40.25	13.51	4.82	1.71	39.71

* Osborne and Mendel, "The nutritive value of the wheat kernel and its milling products," *J. Biol. Chem.*, 37: 557 (1919).

† Calculated by difference.

gives the proximate composition of these different sections of a wheat kernel, which can be considered as representative of all grains. The most important grain products will be discussed in separate sections of this chapter as indicated in the introductory outline.

PART A. *STARCH*

The structure and composition of starch.
The effect of moist heat on starch.
The effect of dry heat on starch.
The appraisal of starches as food.

Two components of grains have hydrophilic-colloidal properties of great importance in food preparation—the proteins and starch. The role of the proteins in foam formation is particularly important in the preparation of leavened mixtures and will be discussed in connection with flours. The behavior of starch is also important in flour mixtures, but its special thickening and gelling properties are basic in the preparation of sauces, gravies, and molded puddings. This discussion will apply not only to cereal starches but also to such noncereal starches as sweet potato, potato, arrowroot, cassava, and tapioca.

The Structure and Composition of Starch

Starch develops in plant tissues in the form of granules. Under the microscope some kinds of starch granules show concentric layers about a central nucleus called the *hilum*, and on X-ray analysis

appear to be at least partly crystalline in structure. The exact chemical composition and physical structure of starch are not known, and the terminology is in a confused state. It is, however, now generally believed that the common starches are composed of two kinds of molecules, both of which yield glucose on complete hydrolysis. In one kind, known as *amylose*, the glucose units are joined to form linear chains containing 100 to 700 glucose units. In the other, called *amylopectin*, from 200 to 500 glucose units are combined in large, highly branched molecules averaging 20 to 25 glucose units per branch.* Ordinary starches contain 24 to 30 per cent of amylose, but the starch of waxy corn (maize), waxy rice, etc., is composed almost entirely of amylopectin and that of wrinkled peas, largely of amylose. Starch granules are characteristic in size and shape for a particular plant species and usually contain such noncarbohydrate components as phosphorus and fatty acids, which may affect their properties.

The Effect of Moist Heat on Starch

Starch is hygroscopic and under ordinary conditions of storage retains about 10 per cent moisture. When it is mixed with cold water, a nonviscous suspension is formed. Undamaged granules do not swell and gradually settle to the bottom. If the cold-water suspension is heated, the granules begin to swell within a range of about 68 to 86 degrees F. (20 to 30 degrees C.). Swelling and thickening in heated starch suspensions is called *gelatinization* and is accompanied by noticeable development of translucency. The product is known as a paste. Flour pastes remain opaque because of the presence of other components.

In the dry starch granule, the molecules of linear amylose are envisioned as twisted and intertwined among the branches of the molecules of amylopectin. Gelatinization is believed to involve molecular disorganization because evidence of the crystalline structure of the original granule disappears. The change has been interpreted in detail as follows: The branches of the amylopectin molecules loosen, permitting the straightening of the amylose chains and their gradual diffusion into the water-filled spaces. In the absence of excess water

* In general, we shall employ the terminology and interpretation proposed by Meyer, "Recent Developments in Starch Chemistry," in *Advances in Colloid Science*, edited by Kraemer, Interscience Publishers, New York, 1942, Vol. I, p. 143.

or mechanical agitation, the amylopectin particles maintain the form of the original granules which are so enlarged by swelling that friction between them develops high viscosity in the paste.

The amylose molecules, however, as a result of the mutual attraction of the hydroxyl groups along the sides of their chains are believed to form colloidal micelles as soon as there is sufficient loss of

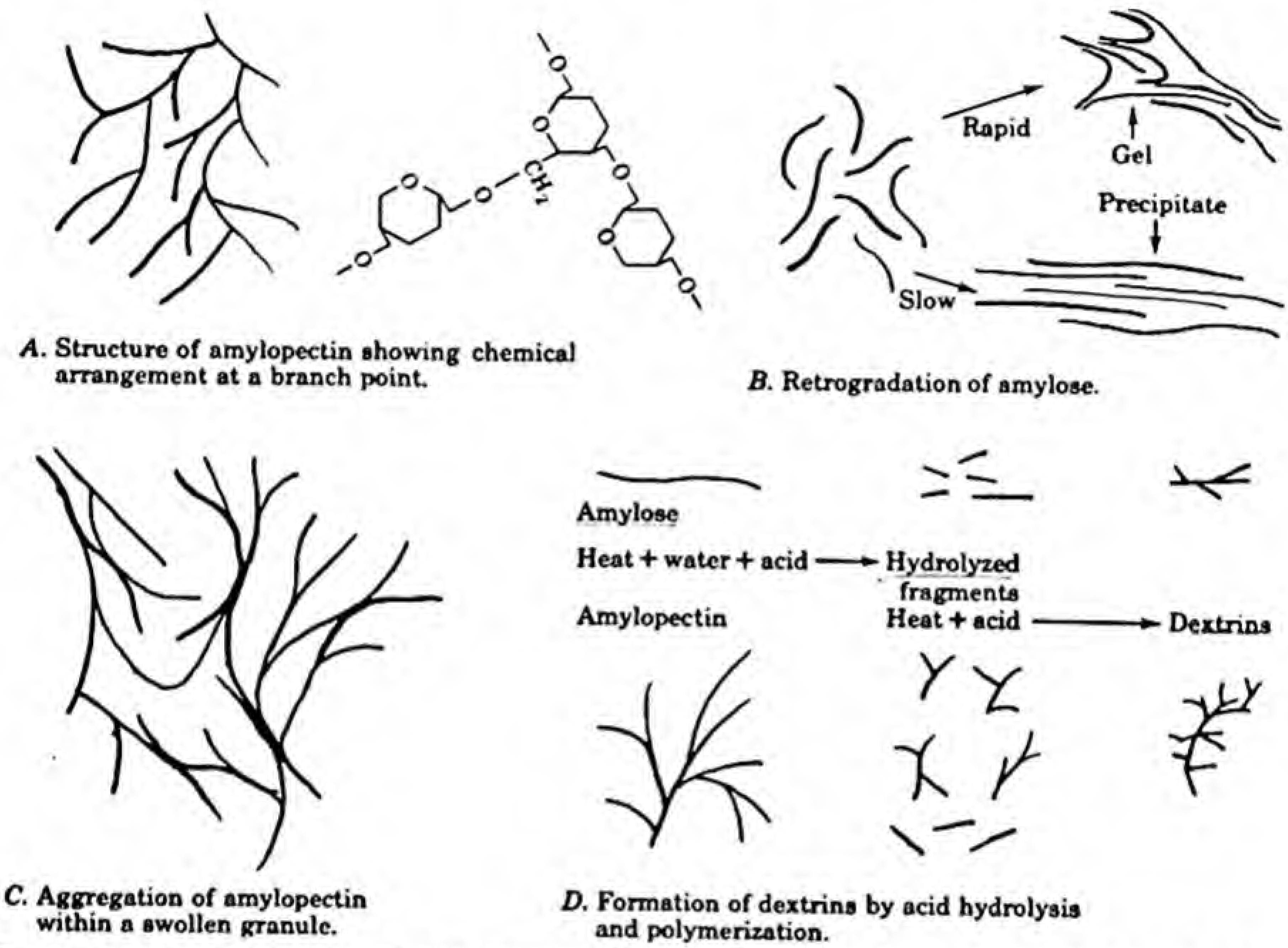

FIG. 42. Representation of the theoretical structure and changes in starch molecules. [After Schoch, *TAPPI*, 35 (No. 7): 22A, July (1952).]

kinetic energy during cooling to permit points of contact and the formation of hydrogen bonding or some other type of linkage. If the concentration of amylose is sufficient to permit rapid association along portions of the molecular chains before there is time for complete orientation, gels are formed which hold the water and amylopectins in their meshes. If, on the other hand, the amylose is very dilute, aggregation is slow, and parallelwise orientation is more complete and results in the formation of insoluble precipitates. (See Fig. 42.) Gel formation and precipitation are both looked upon as representing a partial return to the original crystalline state and are known as *retrogradation*. Given sufficient time, starch gels may

further retrograde, becoming stiff and brittle and perhaps showing syneresis.[2]

Isolated corn amylose when heated in 5 per cent solutions and cooled to room temperature, sets immediately to a firm, rigid gel which cannot be reliquefied by heating. Potato starch develops high viscosity with less tendency to gel formation than cornstarch, perhaps because it contains less amylose and amylose with longer chains than that in corn.* Such molecules would probably untwist more sluggishly and have less capacity to line up with others to form micelles.

When waxy starches, consisting almost entirely of amylopectin, are heated in 5 per cent concentrations, they give viscous suspensions which are relatively stable and have little tendency to gel. Such starches are particularly adapted to thickening products for canning and freezing. When amylopectin is sufficiently concentrated, however, as in 30 per cent suspensions, the paste will form a gel. This is explained as a result of aggregation of some of the longer outer branches of adjacent amylopectin molecules. This more limited bonding permits reversal by heating, which is impossible with retrograded amylose. In the ordinary mixed starches, the amylopectin fraction undoubtedly has a moderating effect on the tendency of the amylose to retrograde (gel and precipitate) merely by its mechanical interference with aggregation.[3]

Complete gelatinization of starch requires the presence of a suitable amount of water and an appropriate temperature and time of heating. Both 1 per cent and 5 per cent concentrations of wheat and cornstarch are 100 per cent gelatinized in 1 or 2 minutes of boiling. But 5 per cent concentrations cooked at double-boiler temperatures, 203 degrees F. (95 degrees C.), require a period of 5 minutes of heating after this temperature is reached if gelatinization is to be complete.[4] Thus, the lower the temperature, the longer is the time required to produce gelatinization.

Several factors found to affect the thickening power of starches and the consistency of starch pastes used in food preparation include

[2] Schoch, in *Advances in Carbohydrate Chemistry*, Academic Press, New York, 1945, Vol. I, p. 247. Meyer, *op. cit.*, Vol. I, p. 143.

* There is also evidence that at least part of the amylose in some tuber and root starches consists of single, forked chains rather than simple, linear chains. This structure would interfere with the parallelwise orientation required for retrogradation.

[3] Schoch, *TAPPI* 35 (No. 7), p. 22A (1952).

[4] Hughes et al., *Cereal Chem.*, 15:795 (1938).

(1) the concentration of starch, (2) the conditions of heating, (3) the kind of starch, (4) the presence of other substances, and (5) the time and temperature of standing after heating is discontinued.

The Concentration of the Starch

The viscosity of a cooked mixture containing starch is in part determined by the proportion of starch to liquid; this is the basis of such simple recipe differences as those between thin, medium, and thick white sauces in which the starch is added in the form of varying proportions of wheat flour. In these mixtures there is enough water to provide for complete gelatinization and high, probably maximum, swelling. In others, where the proportion of liquid to starch is less, or where there is another ingredient competing for a share of the water, gelatinization may be only partially complete when cooking is ended. Incomplete gelatinization resulting from insufficient water occurs in such flour mixtures as bread and perhaps in such a vegetable as potatoes.

In a study of the effect of temperature on concentrated starch suspensions, it was found that the swell in those containing 50 per cent wheat starch was no greater at 203 degrees F. (95 degrees C.) than in those containing 5 per cent at 149 to 158 degrees F. (65 to 70 degrees C.).[5] This difference was considered to be a result of a lack of water for further swelling in the concentrated suspensions. On the other hand, the 50 per cent suspensions formed a moldable paste when heated only to 127 to 131 degrees F. (53 to 55 degrees C.), whereas the formation of a firm gel in a 5 per cent suspension required heating to 203 degrees F. (95 degrees C.) or above. The explanation of the experimenters is that many grains swelling a little appeared to accomplish somewhat the same solid effect in the high concentration as did fewer grains swelling much in the lower concentration. On the basis of the newer concepts of the nature of starch, it is probable that the differences depend upon the relative degree of hydration and consequent loosening of the amylopectin fraction.

The Conditions of Heating

The speed with which high temperatures are reached, the maximum temperature, the length of time of heating, and the amount of agitation during heating are conditions which affect the final stiffness of starch pastes or the viscosity of more dilute suspensions. In

[5] Woodruff and Webber, *J. Agr. Research*, 46: 1099 (1933).

the study mentioned above, the 5 per cent suspensions gave better-formed gels when heating was rapid than when it was slow. The reason for this is unknown. In the 5 per cent wheat suspensions, heating to 203 degrees F. (95 degrees C.) or above gave the firmest gels. Increasing the period of heating at the gelatinization temperature (point where translucency developed) to 15 to 30 minutes improved gelation but never produced maximum stiffness. To obtain maximum swelling and thickness, however, actual boiling of starch suspensions is unnecessary. In fact, long heating at high temperatures diminishes viscosity as a result of the rupturing of the granule structure (amylopectin network). Stirring, especially of large-granule starches such as potato starch, promotes rupturing of the granule structure and decreases viscosity. Under ordinary conditions of food preparation, the development of a cooked taste rather than the development of translucency and thickening is probably the best criterion of doneness, because these latter changes precede the development of optimum palatability.

The Kind of Starch

Starches from different plant species differ in gelatinization properties, as has already been mentioned. For example, in one study, the marked changes in translucency, which were designated as the gelatinization point, occurred at 187 to 189 degrees F. (86 to 87 degrees C.) for cornstarch and at 156 to 158 degrees F. (69 to 70 degrees C.) for potato starch.[6] Such temperatures did not give maximum thickness or gel strength, though these properties also varied to some degree with the kind of starch. Five per cent concentrations of the cereal starches gave well-formed gels, but gels made with this concentration of root starches were poorly formed. When employed in more dilute concentrations, the cereal starches (corn and wheat) gave suspensions characterized by relatively low viscosity and high stability. They could be boiled and agitated to a considerable degree without lowered viscosity, as compared with the noncereal starches (potato, edible canna, arrowroot). The viscosities of a group of starches and starchy materials in suspensions of similar dilution decreased in the following order: potato flour, potato starch, cornstarch, and wheat flour. On the other hand, less cornstarch than any of the other three was required for gel formation. Prob-

[6] Woodruff and Nicoli, *Cereal Chem.*, 8: 243 (1931).

ably these differences are at least in part due to the differing proportions of amylose and amylopectin in the starches from different species.

Different samples of starch of the same species may differ in viscosity and gel strength also. Variety, maturity, and conditions of growth are factors in these variations.[7] In general, starches with grains of larger sizes gelatinize at lower temperature and are more viscous in lower concentrations.[8]

The Presence of Other Substances

Viscosity and gel strength in starch suspensions are altered to a marked degree by the presence of other substances. Sugar, often used in large proportions in starch puddings, increases transparency and tenderness in starch gels, and if present in sufficient amounts will convert a gelatinized suspension of such concentration as would otherwise give a gel into a sirupy mass. This is probably caused by the competition of the sugar for the water, the proportion available for hydration of the starch being thereby diminished. Salt and other electrolytes markedly alter the viscosity of starch suspensions, some diminishing and others increasing viscosity.[9]

If acids are present in a mixture containing starch, more or less hydrolysis takes place, resulting in breaking of the starch molecules. It is probably accompanied by polymerization, but the products differ from the original starch in being more branched and in containing fewer glucose units. This process is known as *dextrinization.* (See Fig. 42.) Fragmentation by acid hydrolysis has been mentioned as the basic technic in producing sirup and glucose from cornstarch. In food mixtures, neither the degree of acidity nor the period of heating ordinarily produces either complete dextrinization or breakdown to glucose, but even a limited fragmentation of starch molecules changes their thickening and gel-forming properties. As the molecular chains of both branched and linear fractions are shortened, viscosity is lowered and the gel-forming tendency reduced. This effect is noticeable in cooking fruit pie fillings and sweet-sour sauces. Such products are more uniform if the acid is withheld until the end of the cooking period.

[7] Knowles and Harris, *Food Res.*, 8: 409 (1943). Harris et al., *Food Res.*, 9: 83 (1944). Harris and Jesperson, *Food Res.*, 11: 216 (1946).

[8] Mullen and Pascu, *Ind. Eng. Chem.*, 34: 807 (1942).

[9] Harris and Banasik, *Food Res.*, 13: 70 (1948).

The Time and Temperature of Standing After Heating

The final viscosity of dilute gelatinized starch suspensions and the gel strength of the more concentrated products are affected by the time of standing after heating is discontinued and by the temperature during standing. Both viscosity and gel strength reach a high point during cooling.

The Effect of Dry Heat on Starch

When dry starch is heated to a temperature of about 320 degrees F. (160 degrees C.), it turns brown in color, becomes more soluble in water, and loses some of its thickening power. The chemical change, like that of starch in acid solutions, is dextrinization, and results in reduced thickening power. Dextrins formed by dry heat are known as *pyrodextrins*. Toasting and cooking in fat are examples of dry heat methods often applied to starchy foods which produce pyrodextrins. They are also formed in the crusty surfaces of flour mixtures during baking. The alterations in color, flavor, and thickening quality associated with dry-heat dextrinization are also of importance in making browned flour sauces. The color and flavor effects of dextrinization are sought in the manufacture of breakfast foods.

The Appraisal of Starches As Food

The sole nutritive contribution of pure starches, like that of sugar, is energy, approximately 1800 calories per pound or 100 calories per ounce.

The effect of cooking on the digestibility of starches has been thoroughly investigated. At one time it was the common belief that raw starches are incompletely digested in the human alimentary tract but that when cooked they are broken down completely and readily to glucose, the form in which they are absorbed. It was thought that amylases have only a slight action on ungelatinized starch granules at body temperature. This belief seemed to be substantiated by artificial digestion experiments outside the body in which raw starch was much more slowly acted upon by amylases than cooked starch.

Experimenters in the United States Department of Agriculture, however, found in digestion experiments with men that raw corn, wheat, and rice starches were so completely assimilated that no trace of them could be found in the feces. Results on raw potato starch were variable, its absorption ranging from only 62 per cent to 95 per cent in seven experiments. Its consumption was accompanied by disagreeable physiological disturbances, formation of gas, and intestinal cramps, symptoms not noted in experiments with other starches.[10] In later experiments, the results of eating a number of other starches less used in this country were studied. Among these, canna and arrowroot starches, which have granules of large size, resembled potato starch in offering more resistance to digestion.[11]

These experiments were repeated, with women as subjects. Again, raw corn, wheat, and rice starches were 100 per cent absorbed with no signs of disturbance.

In a later study in which raw potato starch was fed to human subjects, earlier results were verified both as to large excretion of undigested starch (in some cases as much as 50 per cent or more) and the discomfort resulting from excessive gas formation. But these experimenters surmised that the digestion which took place was a result of bacterial action rather than normal functioning of the body's digestive enzymes.[12] In any event, it seems safe to conclude that any starch will ordinarily be relatively completely absorbed without discomfort if it is cooked sufficiently to be palatable. There is no evidence that such starches as arrowroot and sago are more readily digestible than others and therefore are superior for invalids, as has been maintained.[13]

Commercial starches are highly manufactured products and are not associated with problems of sanitary quality. Maximum palatability develops at a point where the raw taste disappears and is considered to require somewhat more extended cooking than maximum thickening. Cornstarch, which constitutes over 80 per cent of the purified starch used in food preparation, is a relatively inexpensive thickener and source of calories, costing about the same as sugar and a little more than flour on the retail market.

[10] Langworthy and Deuel, *J Biol. Chem.*, 42: 27 (1920).

[11] Langworthy and Deuel, *J. Biol. Chem.*, 52: 251 (1922).

[12] Beazell et al., *J. Nutrition*, 17: 77 (1939).

[13] Anon., *J. Am. Dietet. Assoc.*, 14: 637 (1938).

PART B. *BREAKFAST FOODS AND RICE*

Cooking breakfast foods and rice.
Partially cooked and ready-to-eat breakfast foods.
The appraisal of breakfast foods and rice.
Summary of points to consider in using breakfast foods and rice.

Breakfast foods as they are purchased may be uncooked, partially cooked, or ready-to-eat. The commercially processed products may have been subjected to the dextrinizing and toasting action of dry heat as well as to cooking in steam or water.

Cooking Breakfast Foods and Rice

The principal changes produced by household cooking include softening of the cell wall components and gelatinization of the starch. Cooking produces little or no decomposition of cellulose. Long heating in the presence of moisture, however, softens the fibrous components of whole grains, so that they become soft and easily chewed.

A cooked taste in a cereal porridge as in starch puddings seems to be associated with complete or almost complete gelatinization of the starch. Completeness of gelatinization depends upon the proportion of water present, the uniformity of distribution of the cereal in the water, the temperature of heating, the time of heating, the size of the particles of cereal, the kind (species and variety) of grain, and the fraction of the kernel included.

In an ordinary cereal porridge, enough water is present for relatively complete gelatinization. In one study, it was found that a wheat middlings cereal was completely gelatinized when the proportion of water to cereal was six to one by volume.[14] This approximates the usual directions given.

The dry cereal must be uniformly distributed in the water for gelatinization to be complete. Otherwise, the outer layer of a mass of cereal may gelatinize and restrict passage of water to the interior, resulting in lumpiness. This difficulty may be avoided with coarse cereals by sprinkling them on the surface of the boiling liquid and stirring briskly, but finely ground products should be mixed with a small amount of cold liquid to separate the particles before

[14] Cunningham, *Cereal Chem.*, 8: 403 (1931).

they are incorporated in a hot medium. In the making of white sauces or gravies, the same purpose is served by combining the flour with fat before the liquid is added.

The temperature of the water is an important factor in both speed of cooking and completeness of gelatinization. In a study of gelatinization of corn meal it was found that heating at 203 degrees F. (95 degrees C.) produced 60 per cent gelatinization in 10 minutes or less; 194 degrees F. (90 degrees C.) produced 50 per cent in the same period; and 185 degrees F. (85 degrees C.) produced only 30 per cent in 15 minutes.[15] The same experimenters also employed a granular wheat cereal and found that preliminary boiling for as little as 1 or 2 minutes considerably accelerated gelatinization. With no preliminary boiling, 30 minutes at 203 degrees F. (95 degrees C.) resulted in 95 per cent gelatinization, but when the cereal was first boiled 1 and 2 minutes this percentage of gelatinization was obtained in the first case in 15 minutes at 203 degrees F. (95 degrees C.) and in the second case in 10 minutes at the same temperature. Thus the common method of boiling a cereal briefly and finishing the cooking in a double boiler is shown to be a desirable one.

It is, of course, easy to understand that size of particles is an important factor in speed of cooking of cereals. Gelatinization cannot proceed until water has reached the starch. In the study reported above, a fine granular wheat cereal attained maximum gelatinization in 2 minutes of boiling but a coarser type required 5 minutes. Whole-wheat flour can be cooked in 20 minutes or less, but whole-wheat kernels require 4 hours on account of their larger size.

Fractionation is also a factor in speed of penetration of water and hence in rate of cooking. Average polished rice cooks in about 20 minutes, whereas two or three times as long is required for the brown rice encased in its bran. Preliminary soaking for an hour is a recommended method of shortening cooking time for the latter.

Not only species but also variety of grain affects the time required for cooking. When tests were made by the BHNHE to determine the cooking time desirable for each of seven varieties of rice, it was found that one variety cooked in as little as 16 minutes but another required 24 minutes. For this reason best results are obtained when varieties are not mixed before marketing.[16]

[15] Cunningham, *ibid.*

[16] Stienbarger, *U. S. Dept. Agr., Leaflet* 112 (1935).

Partially Cooked and Ready-to-Eat Breakfast Foods

It is now possible to buy many breakfast foods which are partially or completely cooked. Such flaked products as rolled oats and wheat are made by partial cooking in steam followed by rolling and drying the whole kernel. "Quick cooking" oats and wheat are made from cut grains which roll into smaller and thinner flakes with the result that the cooking in the household may be completed in a shorter time. There has been some doubt about the adequacy of the 3-minute to 5-minute period recommended on the package, but it has been found in tests with both children and adults that, for 85 per cent of the subjects, rapid boiling for this period gives a product as acceptable as one cooked longer, whereas cooking 10 to 15 minutes gives a product not nearly so well liked.[17]

Ready-to-eat breakfast foods are completely cooked at the factory. The cooking is performed by puffing, flaking, or baking a dough. In puffing, the grains are subjected to tremendous steam pressure which, when released, causes the starch grains to burst and inflate the kernels. Flakes are manufactured from grits (coarsely ground kernels) which are cooked with sugar and malt. Dough types are shredded, crumbed (as in grapenuts), or made into other shapes.

The principal problem in connection with the successful sale of the ready-to-eat breakfast foods has been solved by the use of moistureproof packages which preserve the crispness of the material. When their moisture content rises above 7 per cent, they become tough. This happens in ordinary atmospheres as a result of their hygroscopicity, unless precautions are taken to prevent it.

The Appraisal of Breakfast Foods and Rice

Nutritive Quality

Breakfast foods constitute only a small fraction of all cereal products, the typical daily serving averaging about 1 ounce in the dry state. This furnishes about 100 calories and at least its share of protein, a serving of oats containing substantially more protein than other grains. Whole-grain products provide more than their share

[17] Denton, *J. Home Econ.*, 24: 243 (1932).

of iron, but grains in general are only minor sources of calcium. (See Table LVII.)

Provitamins A occur in a measurable amount only in yellow corn meal, but that amount is relatively insignificant. Whole grains provide more than their share of thiamine, and riboflavin and niacin in varying amounts—corn and oats averaging the smallest proportion of niacin. Wheat contains at least twice as much niacin as corn, a fact that helps to explain the former high incidence of pellagra in the southern states where corn meal is commonly used instead of wheat flour. However, certain strains of corn are so much above average in niacin that it has been suggested that they might well be propagated, particularly for products intended for human consumption. Corn also has a deficiency of the amino acid tryptophan, which may be converted to niacin by intestinal synthesis. Milk, which is nearly always served with a breakfast cereal, remedies this deficiency. Soybean flour or grits is far superior to grains in protein, calcium, iron, thiamine, and riboflavin.

Subdivision does not change the nutritive value of cereals, but fractionation alters the proportion of vitamin B complex and minerals markedly, because these are in lowest concentration in the endosperm. In rice, rye, barley, and wheat, most of the thiamine is near or in the germ. Iron is found in largest proportion in the bran layers. Thus refined breakfast foods are much inferior to the whole-grain types in iron, thiamine, riboflavin, and niacin. Losses of thiamine are further increased by puffing and toasting in certain ready-to-eat types. However, nearly all brands of breakfast foods are now fortified with added iron, thiamine, and niacin to approximate whole-grain values. This is indicated on the label. Riboflavin is not usually added because the amount in the original grain is relatively insignificant and because it might contribute a noticeable yellow tinge in white types such as rice. Losses in ordinary cooking are insignificant.

The vitamin and mineral value of rice is improved by enrichment and by parboiling or steaming the whole kernel, which equalizes the distribution of nutrients throughout the kernel and causes the portion of the germ richest in thiamine to be retained during milling. It is then dried and milled, the resulting product retaining more than half as much thiamine, riboflavin, and niacin as the original. One of these products is known as converted rice. Milled, parboiled rice

Table LVII. The nutritive contributions of one ounce of dry breakfast cereals, given as percentages of the *Recommended Allowances* for a physically active man

[Babcock, *N. J. Agr. Expt. Sta. Bull.* 751 (1950)]

Food, measure,* and description	Energy	Protein	Calcium	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Ascorbic acid
Barley, pearled	3	3	(0)	(4)	(0)	2	1	5	(0)
Corn meal									
whole ground	3½	4	(0)	6	3 †	7	2	4	(0)
degermed	3	3	(0)	2	1½	2½	1	1½	(0)
enriched, degermed	3	3	(0)	6	1½ †	7	4	6	(0)
Corn flakes, about 1 cup	3	3	(0)	2	(0)	1	1	3	(0)
Corn flakes fortified with thiamine, niacin, and iron, about 1 cup	3	3	(0)	5	(0)	7	1	4	(0)
Rolled oats	3	5	1	9	(0)	10	2	1½	0
Rice, brown	3	2½	1	4	(0)	5	1	8	(0)
converted	3	2½	½	1½	(0)	4	½	6	(0)
white	3	2½	1	1½	(0)	1	½	2½	(0)
flakes, about 1 cup	4	3	1	4	(0)	1	2	2	(0)
flakes, about 1 cup added thiamine and niacin	4	3	1	4	(0)	9	2	11	(0)
puffed, 2 cups	3	2	½	4	(0)	2	2	2	(0)
puffed, 2 cups, added thiamine and niacin	3	2	½	4	(0)	8	2	10	(0)
Rye meal, whole	3	6	1	9	(0)	10	3	4½	(0)
Soybean grits, about ⅕ cup medium fat	2	15	6	27	½	14½	5	4½	(0)

Food nutrients span the columns Energy through Ascorbic acid.

Wheat									
whole meal	3	4½	1	7	(0)	9	2	7½	(0)
rolled	3	3½	1	7	(0)	6	1½	7	(0)
farina	3	4	1	2	(0)	1	1	1½	(0)
farina, enriched	3	4	1	3	0	6	3½	2	(0)
flakes, about ¾ cup	3	4	1	6	(0)	1½	2½	8	(0)
flakes, about ¾ cup added iron, thiamine and niacin	3	4	1	9	(0)	9	2½	10½	0
puffed, about 2 cups	3	4	1	6	(0)	1½	2½	8	(0)
puffed, about 2 cups, added iron, thiamine, and niacin	3	4	1	9	(0)	9	2½	10½	(0)
shredded, 1 large biscuit	3½	4	1½	8½	(0)	4	1½	8½	(0)
bran, breakfast cereal, about ½ cup	2½	5	3	26	(0)	7½	6½	38½	(0)
germ, about ½ cup	3	10	2½	19	(0)	37	12	8½	(0)

* One ounce of dry cereal makes from ½ to ¾ cup of cooked cereal.

† Yellow corn meal. White has only a trace.

is clear and slightly yellow in color but cooks creamy white. It also has a reduced tendency to become sticky on cooking and standing.

Clean, packaged rice needs no washing before cooking. To retain the highest food value only the amount of water which will be absorbed should be added so that none will be left to be discarded. This is especially important when cooking brown or processed rice, both of which have been found to lose half their thiamine when cooked in large amounts of water. Polished rice, which has little thiamine to begin with, loses only about one-tenth under the same conditions. When a volume of water equal to about 2¼ times the volume of rice is employed, it is completely absorbed and results in retention of 70 to 80 per cent of the thiamine. Baking in an oven at 400 degrees F. (204.4 degrees C.) for 45 minutes has been found to produce excellent retention; cooking in a pressure saucepan, poor retention as well as a less fluffy product.[18] The practice of frying or toasting brown rice and adding water for further cooking, as called for in many Spanish or Oriental recipes, may result in particularly poor thiamine retention, from 46 to 72 per cent remaining after frying and from 50 to 91 per cent after toasting. Most of the inactivation occurs during the stage of dry heat cooking.[19]

Cooking losses by solution do not occur in the preparation of such breakfast foods as rolled oats and farina, but prolonged heating inactivates part of the thiamine. Heating for periods up to 15 minutes is insignificant in its action and is usually sufficient for palatability.[20]

Several southern states have passed legislation making enrichment of ordinary degerminated corn meal with iron, thiamine, and niacin compulsory. Whole-grain corn meal should also be fortified with niacin, at least in those areas where it is largely used instead of wheat flour, but technical difficulties associated with the large number of small mills doing local grinding have retarded this development.

A number of experimental studies have shown that puffing and a high degree of toasting reduce the tissue-building value of cereal proteins. This results at least in part from damage to the essential amino acid *lysine*, but is ordinarily of little significance in human

[18] Vinacke, *J. Home Econ.*, 43: 641 (1951).

[19] Kennedy and Tsuji, *J. Am. Dietet. Assoc.*, 28: 114 (1952).

[20] Lincoln et al., *Cereal Chem.*, 21: 274 (1944).

nutrition, because such a small proportion of our protein comes from these sources.[21]

Breakfast food manufacturers through advertising maintain that a good breakfast pattern must include a breakfast food, but from a nutritional standpoint the only advantage of these foods over a corresponding amount of enriched or whole wheat bread or toast is the more frequent serving of milk with them. If one obtains the recommended amount of milk in other ways, it makes no essential differences which form of grain product is chosen, provided it is a whole grain or enriched product.*

Digestibility

The method and amount of cooking breakfast foods have not been shown to be important in relation to the completeness with which they are digested. When human subjects ate raw white flour, graham flour, and corn meal, these were practically as completely digested as when cooked, though the subjects "experienced general nervousness at the beginning of the experiments and were subject to occasional headache or other slight bodily discomfort at times during the experiment."[22] In other experiments, the completeness of absorption of rolled oats and corn meal was also unaffected by length of cooking period, but palatability was improved by cooking more than 10 minutes.[23]

Test-tube experiments indicate, however, that the time required for digestion of starch in oat, corn, wheat, and barley products is less after cooking, but there is little difference between the results of 20 and 90 minutes of cooking.[24] Longer cooking up to 1 hour for a number of breakfast foods has been found to increase the speed of digestion of protein somewhat more than that of starch, probably because of the increased penetrability of the cellulose by the enzyme solution.[25]

As in other foods, the length of time that cereals stay in the stomach varies more with the individual than with the method of

[21] Sure, *Food Res.*, 16: 161 (1951).

* Two slices of whole-wheat bread or toast or one and one-half slices of enriched white bread or toast approximate a serving of breakfast food in nutrients provided.

[22] Langworthy and Merrill, *U. S. Dept. Agr., Bull.* 1213 (1924).

[23] Rose, *J. Home Econ.*, 14: 9 (1922). Kramer and Halstead, *J. Home Econ.*, 17: 75 (1925).

[24] Noble et al., *Cereal Chem.*, 10: 243 (1933).

[25] Carman et al., *J. Nutrition*, 2: 91 (1929–30).

preparation. When a wheat endosperm and rolled oat cereal cooked 20 minutes and a ready-to-eat corn endosperm product were compared, 80 to 90 per cent of the protein of each had left the stomachs of several subjects in 2 hours. Neither precooking, as of "quick" rolled oats, nor the proportion of bran up to that provided in a whole cereal had an important consistent effect.[26]

So far as present evidence indicates, cooking that gives a desired palatability will also result in a satisfactory rate of digestion, at least for normal adults. Young children and adults who have sensitive digestive tracts may benefit from the increased softening of fiber produced by more extended periods of heating.

The completeness of digestion of cereals is more affected by the degree of fractionation than by the method and time of cooking. Milled cereals are more completely digested than whole cereals, because cellulose is most abundant in the bran. In fact, bran and 60 per cent bran flakes are among the most effective of foods in their laxative quality.[27] The peculiar effectiveness of bran in preventing atonic constipation is probably caused by the resistance of its cell-wall components to digestion, as contrasted with the less resistant fiber of vegetables,[28] and is associated with increased frequency of evacuation in individuals who habitually exceed a 24-hour period.[29] But some individuals find the comparative harshness of bran and products containing it too severe in their action on the intestinal walls. Children, especially, are often intolerant of foods high in cellulose. Consequently, the eating of bran should not be advocated indiscriminately. On the other hand, many persons find whole-grain cereals or bran valuable sources of roughage to combat atonic constipation. Although bran may be eaten by some to excess, complete removal of this portion of cereals from the diet by the exclusive use of refined cereals undoubtedly is responsible for much constipation.[30]

Malted cereals have been treated with malt, a preparation of dried and powdered sprouted barley grains, which contains an abundance of the starch-splitting amylases. Claims have often been made that such "predigested" cereals are especially desirable, but, except for the change in flavor which many people may relish, these cereals

[26] Clough et al., *J. Nutrition*, 3: 1 (1930).

[27] Hoppert and Clark, *J. Am. Dietet. Assoc.*, 21: 157 (1945).

[28] Cowgill and Anderson, *J. Am. Med. Assoc.*, 98: 1866 (1932).

[29] Fantus et al., *J. Am. Med. Assoc.*, 114: 404 (1940).

[30] Rose et al., *J. Am. Dietet. Assoc.*, 8: 133 (1932).

have no particular advantage for those in ordinary health. The amount of predigestion is limited, and normal individuals are equipped with a digestive mechanism which digests cereals readily.[31]

Sanitary Quality

Dry cereal products are not media favorable for the multiplication of microorganisms. Cooking ensures safety from any sources of contamination to which they might have been exposed during production and marketing. In general, this group of foods is not associated with any particular health problem.

Palatability

Wheat and rice are the preferred cereals throughout the world, probably in part because they are the most bland in flavor, particularly in their milled forms. Breakfast food manufacturers constantly devise new processes which vary flavors and textures and make it possible to avoid monotony. The relation of amount of cooking to appetite appeal has been discussed.

Economy

A simple way of estimating the relative economy of all whole-grain or fortified breakfast foods as purchased is to compare prices per ounce. The cost of some kinds will be found to be as much as four times that of others.

In nutritive quality, digestibility, and sanitary quality, ready-to-eat breakfast foods have no advantage over those cooked in the household. Rational demand for them rests upon their palatability and the saving in time, fuel, and labor involved in their preparation, but it is inflated by sales pressure. In fact, the commercial possibilities of utilizing technological skills and promotional advertising to inflate the market value of what was originally a simple inexpensive product have perhaps been exploited to the same degree in the case of no other food, and they complicate greatly problems of distribution by the market and selection by the consumer buyer. The cost of ready-to-eat breakfast products varies greatly, but when compared with that of similar household-cooked products, they are often expensive, whereas cereals should be among the cheapest foods that we eat.

[31] Ivy et al., *J. Nutrition*, 12: 59 (1936).

In general, breakfast foods of the less costly kinds are inexpensive sources of calories and protein and, if whole-grain or fortified, of iron, thiamine, and niacin.[31a]

Summary of Points to Consider in Selecting and Using Breakfast Foods and Rice

1. Grain products are generally our least expensive sources of calories and protein. The whole-grain or enriched types furnish more than their share of the iron and thiamine that we need. Whole-grain products, except those made from oats, and all enriched types also provide extra niacin. All grain products are low in calcium, lack ascorbic acid, and, with the exception of yellow corn, vitamin A value. Milled grain products are relatively deficient in all minerals and vitamins.

2. Breakfast foods should be mainly of whole-grain or enriched types. It is important to read labels for information on these points. The only advantages of a breakfast food as compared with an equivalent amount of whole-grain or enriched bread or toast are (*a*) the breakfast food is usually served with milk or light cream and (*b*) if served hot, the breakfast food may give added appetite appeal to a meal in which there is no other hot food.

3. Household methods of cooking breakfast foods result in only insignificant nutritive losses, and the time required to produce satisfactory palatability is sufficient for optimum digestibility.

4. Many breakfast foods are sold at prices inflated by high advertising costs. Comparative values can be judged on the basis of price per ounce. Usually plain rolled oats or wheat offer the best value for the money.

5. Brown, "converted," or some other type of enriched rice should be the type chosen if it is to be eaten often. Such rice should be cooked only in the amount of water that it will absorb to minimize nutritive losses.

6. The nutritive value of all grain products is enhanced by mixing or serving them with milk or by adding soybean products.

7. In general, we should continue to eat a portion of our grain products in the whole-grain form for their roughage and the possible unknown nutrients that they may contain.

[31a] Rollins, *Cornell Univ. Agr. Expt. Sta. Bull.*, 845 (1948).

PART C. *PASTES—MACARONI AND RELATED PRODUCTS*

Macaroni, spaghetti, vermicelli, noodles, and products of similar composition but novel shapes, such as alphabets and sea shells, are often called alimentary pastes. They are made from coarsely ground endosperm, which is a product of roller milling known as middlings, and flour. The middlings from durum wheats which make superior products of this type, are called semolina. Farina, the middlings from other wheats, is also used in the manufacture of pastes. Semolina products have a clear, yellow color and are hard, brittle but pliable, and translucent. Pastes made from farina break more easily and are grayish white in color.

The manufacture of pastes consists of mixing and kneading a stiff dough made from boiling water, the middlings, and flour, forcing the dough through perforated discs which give the characteristic shapes, and drying. Semolina makes stiffer doughs with less water than farina and hence is quicker-drying.

According to the federal definition, macaroni is the tube-shaped product 0.11 inch to 0.27 inch in diameter. Spaghetti is either tube or cord-shaped, varying from 0.06 inch to 0.11 inch in diameter, and vermicelli is cord-shaped, having a maximum diameter of 0.06 inch. Disodium phosphate is an optional ingredient which speeds up cooking. Other optional ingredients include egg white, certain seasonings, and gum gluten. Milk macaroni products are made from doughs moistened with some form of milk. Whole-wheat products contain whole grain products exclusively. Wheat and soy combinations must contain at least 12.5 per cent of the combined weight of wheat and soy as soy flour. Vegetable macaroni products contain not less than 3 per cent of the weight of the finished product in the form of certain vegetables.

Noodles are ribbon-shaped pastes made from the same types of wheat products as macaroni, but in addition they must include not less than 5.5 per cent by weight of egg or egg yolk solids. Noodle mixtures may also be sold in macaroni, spaghetti or vermicelli forms, and variations of the wheat and soy, and vegetable noodle types of products are defined.

Both macaroni and noodle products are now available in enriched forms. The definitions specify that each pound shall contain from 4 to 5 milligrams of thiamine, 1.7 to 2.2 milligrams of riboflavin, 27

to 34 milligrams of niacin, and 13 to 16.5 milligrams of iron. Optional enrichment ingredients are vitamin D, calcium, and wheat germ in specified amounts.

The Appraisal of Pastes

The food value of the pastes is largely that of the middlings and flour from which they were made, except when they are fortified. (See values for farina in Table LVII.) The proportion of egg in noodles is so small that it adds little food value. Like farina, the plain pastes are primarily energy foods having a value of about 100 calories per ounce in the dry form. The unenriched types furnish their share of protein, iron, and niacin, but are lacking in vitamins A and C, and low in calcium, thiamine, and riboflavin. The enriched forms furnish extra amounts of thiamine, riboflavin, niacin, and iron. (See Table LVIII.) They should be cooked with no

Table LVIII. The nutritive contributions of pastes, given as percentages of the *Recommended Allowances* for a physically active man

[Babcock, *N. J. Agr. Expt. Sta. Bull.* 751 (1950)]

(Values are for 1 ounce of the dry product which equals about ½ cup cooked macaroni or spaghetti or 1 cup of cooked noodles.)

Food, measure and description	Energy	Protein	Calcium	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Ascorbic acid
	Food nutrients								
Macaroni	3	4½	½	3	(0)*	1½	1	3	(0)
enriched	3	4½	½	6	(0)	14½	5	10	(0)
Noodles	3	4½	½	4	1	3	1½	4	(0)
enriched	3	4½	½	6	1	14½	5	10	(0)
Spaghetti	3	4½	½	3	(0)	1½	1	3	(0)
enriched	3	4½	½	6	(0)	14½	5	10	(0)

* Imputed values in parentheses.

excess water or the materials used in enrichment will be largely lost by solution.

The digestibility properties of pastes are similar to those of the particular grain products included in them. No particular sanitary problems are involved in their use.

Desirable palatability qualities in cooked pastes include capacity to hold their shape and swell to about twice their original size. They should also be tender but firm without becoming sticky. Products

of poor quality tend to have a starchy taste and a sticky, pasty, texture when cooked.

Macaroni and spaghetti at retail prices cost about the same as rice and the cheaper breakfast foods, but almost twice as much as flour. Noodles are more expensive than other pastes.

PART D. *FLOURS*

Flour milling.
Properties affecting flour quality.
Types of flour on the retail market.
  Whole-wheat flour.
  White flours.
  Flours other than those made from wheat.
The appraisal of flours.
Summary of points to consider in selecting and using flours.

Flours are finely ground grains or fractions of grains. The simplest way to produce a flour is to grind the whole grain. This type of flour, however, has the disadvantage of a whole cereal in possessing poor keeping quality. Further disadvantages, at least in relation to present standards, are the relatively coarse texture and dark color of products made from whole-grain flours as compared to products made with flours composed of the endosperm alone. Old-fashioned white flours were obtained by sifting wheat ground in a stone mill. This method separated the whitest part from the coarser bran and germ which did not pulverize so completely as the endosperm, but the resulting flours were neither so white nor of such high baking quality as the products of a modern roller mill.

FLOUR MILLING

Modern milling may be described as a process in which the grain is separated into portions of different qualities by a series of crushings and siftings. The wheat is first cleaned thoroughly, then moistened or "conditioned" to toughen the bran. The next step, known as breaking, is accomplished by feeding the wheat through a number of sets of corrugated rolls placed far enough apart to crush the kernels into coarse fragments, but largely detaching the endosperm from the bran. At each crushing, some of the endosperm becomes sufficiently fine to pass through flour sieves and is known as *break* flour. The coarser particles of endosperm are called *mid-*

dlings because they are too large for flour but small enough to go through sieves that remove most of the bran. Some bran particles are small enough to go through with the middlings and are removed by air currents, a process called *purification*. The modern flour mill has been developed to eliminate these bran fractions to a very high degree, and flour quality is based on the relative completeness of the separation. Because the minerals of the grain are present in largest proportion in the bran, the ash content of a flour is an indication of its degree of refinement, and legal limits have been established for that present in white flour.

After purification, each lot of middlings is "reduced," that is, passed between a series of smooth rolls, each set of which produces some flour and progressively smaller middlings. Parts of the germ which were attached to the coarse middlings are flattened by the reducing rolls and then removed from the flour and fine middlings by sifting. Gradually, any remaining particles of bran are also sifted out because they resist pulverization more than the endosperm. The particles of bran and endosperm separated from the middlings are known as *shorts* and, like the coarse bran, are sold as animal feeds.

As this description of the milling process indicates, there are many streams of flour in a typical roller mill, including about five streams of break flours and six or more from reduction of the middlings. These streams differ in their freedom from bran and germ and in the part of the endosperm that they represent. The break flours and those from the last reductions are of inferior baking quality. These differences make it possible to produce several grades of flour from the same wheat.

The bran makes up about 14.5 per cent of the kernel, the embryo 1.5 per cent, and the endosperm 84 per cent. (See Table LVI for the proximate compositions.) Theoretically, about 82 to 85 per cent of the wheat should appear as white flour, but at the present time only about 72 to 75 per cent is separated in this form. There are on the market today wheat flours which contain the whole kernel and are called *graham*, *whole wheat*, or *entire wheat flour*. Others have only a portion of the bran removed and may be known as *bolted graham* or *bolted whole wheat*. The three grades of white flour are *straight*, *patent*, and *clear*. If it were true to its name, a straight flour would contain all the flour streams coming from the mill. In practice, it is customary to remove 2 or 3 per cent of the poorest streams, those containing the outer layer of the endosperm

and fine particles of bran—consequently, so-called straight flour contains about 97 to 98 per cent of the total flour. Patent flours are made from the very whitest streams only, *short patents* being blends of 60 to 80 per cent, *medium patents* 80 to 90 per cent, and *long patents* 90 to 95 per cent of the flour. Clear flours consist of the flour streams withheld from the patent types.

PROPERTIES AFFECTING FLOUR QUALITY

The properties of flours of greatest interest to consumers are (1) color and (2) strength.

Color

The popular demand is for a very white flour, probably because whiteness is associated with purity. This association grew up in the days when wheat was less carefully prepared for milling than it is at present and when a dark color was the result of the presence of dirt. Today, whiteness in flour is dependent upon separation of the endosperm from the bran and germ portion of the kernel, and the bleaching of the natural carotenoids which give a creamy tint to the endosperm itself. Flour will bleach naturally, though very slowly, in storage by oxidation of the pigments, but several supposedly noninjurious chemicals, including certain oxidizing chlorides, are commonly employed. Chemical bleaching of flour does not in any way conceal inferiority and may actually improve its baking quality.

Strength

The outstanding characteristic of wheat flour on which its culinary versatility is founded is its *strength,* essentially its capacity to retain gas (air, water vapor, and carbon dioxide) and thus develop a foam structure. Strong flours are those which can hold comparatively large volumes of gas. They are preferred for making bread and other yeast-leavened products. Weaker flours are suitable or even more desirable for pastry, crackers, and sweet mixtures.

Although starch is a major component of all flours, baking strength is dominated by the proteins. In wheat flours, the individual particles are essentially, in structure, small pieces of protein gels low in water. The gels hold the starch granules within their meshes and contain molecularly dispersed minerals, sugar, vitamins, and water. When water is added to flour, the starch grains

absorb only a small amount, which causes them to swell slightly and adsorb an additional quantity on their surfaces. The colloidal particles of the dried protein gels imbibe cold water readily, however. If water is added to a relatively small proportion of flour, a suspension is formed and most of the flour components settle out.

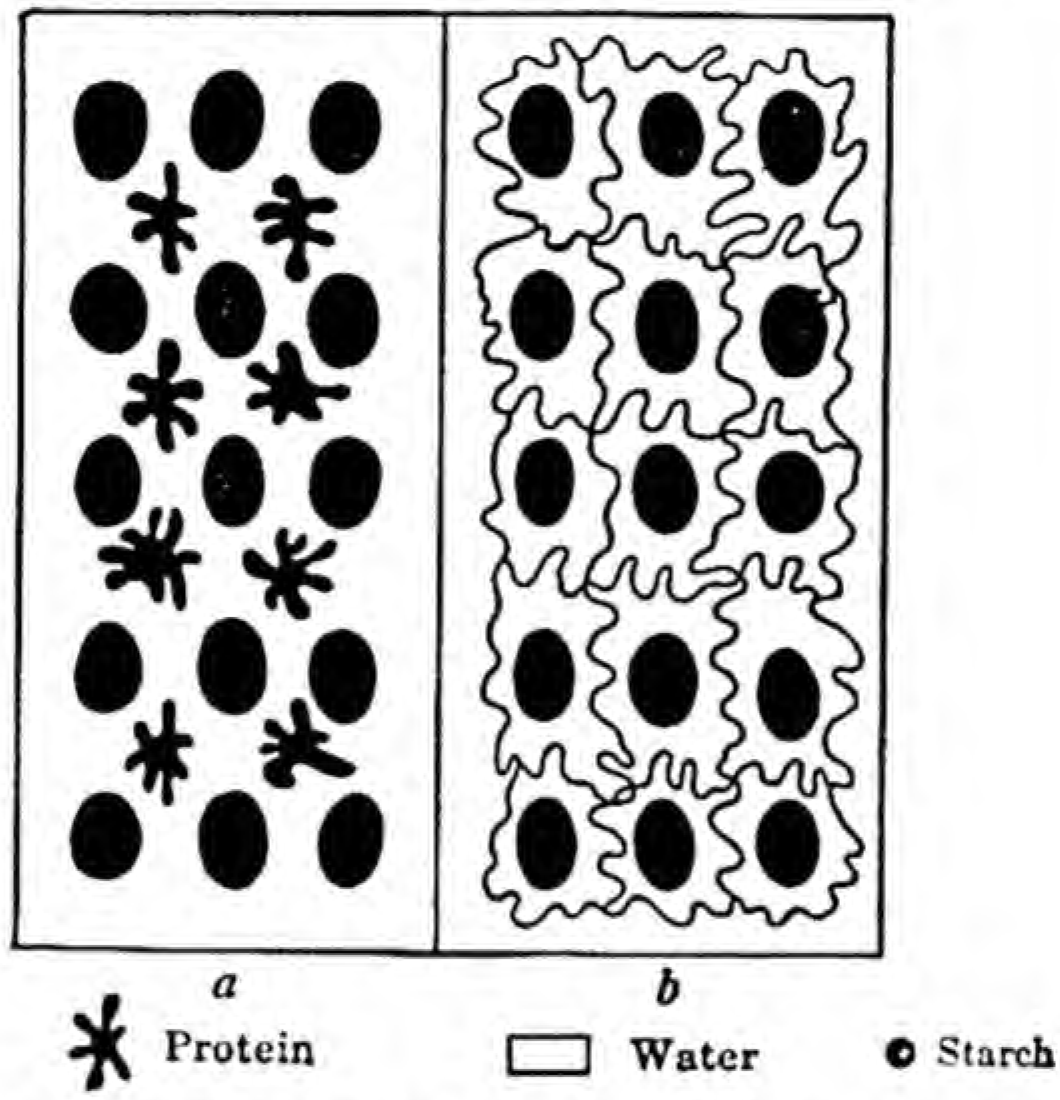

FIG. 43. Diagram to illustrate the colloid structure of dough (*after Swanson*). Starch and water form a two-phase system; the same is true of protein and water. Before the dough is formed both protein and starch are in a discontinuous phase. (*a*) As soon as the dough is formed, there are two continuous phases, water and the gluten meshwork, whereas starch remains as a discontinuous phase. (*b*) Because water wets the starch grains and because of the strength of the water films around these starch grains, starch has an influence on the colloid quality of the dough. But dough from flour has a quality different from a mixture of starch and water, because the protein particles, adhering to each other, form strands which help to bind this whole mass together. The inherent structure of the particles forming these strands and the environment, which affect adherence of the particles to each other, determine the quality of dough of one flour as compared with that of another.

To form a dough, it is necessary for the protein micelles to be close enough together to make contacts. Under conditions where this is possible, the colloidal particles of wheat flour protein have the peculiar property of adhering to each other so strongly that additional water may be used to wash out the starch and most of the substances in true solution, leaving a yellowish, rubbery mass known as *gluten*. It is the gluten formed in moistened flour which has the capacity to hold gas and is responsible for its strength. (See Fig. 43.)

The composition and structure of gluten are not clearly understood. Earlier theories held that gluten consisted mainly of two proteins, *gliadin* and *glutenin*. Improvements in methods of physicochemical research have cast doubt on this interpretation. Two related theories are currently favored. One holds that gluten is a heterogeneous, complex structure consisting of a large number of components. The other maintains that the actual components are limited in number and that the many and varied protein fractions that have been isolated from gluten are the result of extensive and complex aggregation and interaction of these few components. However, until further research clarifies this problem, it is convenient to retain the terms gliadin and glutenin for the essential gluten components.[32] In any event, it has not been possible to show that differences in baking quality are related to differences in the chemical composition of gluten. It seems probable that variations in physical state are the controlling factor.

Differences in the strength of flours are determined in part by the variety of the wheat from which they were manufactured and conditions, both of soil and climate, under which the wheat was grown and ripened, and of storage. Wheats grown in the United States which are used for flours are of two types, hard and soft. Hard wheats are raised mostly in the Great Plains area between the Rocky Mountains and the Mississippi Valley north and west of Missouri; they produce the strongest flours. Soft wheats, producing weaker flours, are grown in the regions between the Atlantic coast and the Great Plains and also along the Pacific coast. Hardness is associated with dry seasons at maturing time and softness with moistness and coolness.

Practical household tests which may be applied to differentiate the two types of flours include:

1. *Color.* Hard-wheat flour is more creamy than soft-wheat flour.
2. *Texture.* Hard-wheat flour feels granular when rubbed between the finger-tips; soft-wheat flour feels velvety, like starch.
3. *Cohesiveness.* When squeezed by the handful and released, hard-wheat flours leave a mold that breaks up more readily than that formed with soft-wheat flours.
4. *Weight.* One quart of hard-wheat flour sifted once weighs 16 to 17 ounces or more, or about 112 grams per cup. Under the

[32] Blish, "Wheat Gluten," in *Advances in Protein Chemistry*, edited by Anson and Edsall, Academic Press, New York, 1945, Vol. II, p. 346.

same conditions, soft-wheat flour weighs about 14 to 15 ounces, or about 98 grams per cup.

Not only the kind of wheat and the conditions under which it is grown but also the flour milling process itself may affect the strength of a flour. As mentioned previously, whole-grain flour does not make a product of as large a volume or as fine a texture as a milled flour composed of the endosperm from which practically all the bran and germ have been eliminated. In fact, the more completely the bran and embryo are removed, the lighter and finer grained is the product. It is not entirely known just what components of bran and germ are responsible for these effects. The milling process may also affect flour strength by the degree of fineness of grinding as well as by the degree of fractionation. Very fine grinding, for example, tends to weaken flour strength.

Certain enzymatic changes which occur during the holding of some flours, known as aging, result in improved flour quality. Oxidizing agents such as chlorine dioxide, which are employed by the miller for bleaching, or flour "improvers," which are used by the commercial baker, may also have this effect. However, the strength of flour may be diminished by the presence of certain components of wheat or by other ingredients. For example, the fine particles of embryo found in low-grade flours are said to be the cause of their low strength.

In actual practice, the flours produced in the larger mills are not manufactured from shipments of wheat from a single area. To maintain a supply of flour which will give uniform products, it is necessary to mix different lots of wheat. Wheat varies not only from one area to another but from one field to another. Various milling and baking tests are employed at large mills to ascertain the characteristics of each lot of wheat. Then a blend is prepared which gives a standard product. Probably the reason why a homemaker considers one brand of flour superior to another is that this standardization permits her to secure uniform results from different lots when she follows the same procedure.

TYPES OF FLOUR ON THE RETAIL MARKET

The retail market offers whole-grain flours and several types of white flour made from wheat, as well as a limited number of flours from grains other than wheat.

Whole-wheat Flours

According to federal definition, *whole wheat, graham,* and *entire* wheat flours are synonymous designations for the product manufactured by grinding cleaned wheat which passes through sieves of designated sizes. They contain all of the kernel. Limited amounts of malt or malt preparations may be added to remedy enzyme deficiencies, and specified chemicals may be employed for bleaching and aging, but this must be indicated by the word "bleached" on the label.

White Flours

Products labeled either *flour* or *white flour* are by definition prepared by grinding and bolting cleaned wheat to a size which passes through bolting cloth of designated size. The degree of freedom from bran and germ is also specified and measured by the percentage of flour ash. Addition of malt products and bleaching and artificial aging by certain chemicals are permitted, but bleaching must be indicated on the label.

Enriched flours are defined to contain additions of 2.0 to 2.5 milligrams of thiamine, 1.2 to 1.5 milligrams of riboflavin, 16.0 to 20.0 milligrams of niacin, and 13.0 to 16.5 milligrams of iron per pound. Other optional additions are vitamin D at the rate of 250 to 1000 USP units, calcium 500 to 625 milligrams, both on a pound basis, and wheat germ not more than 5 per cent by weight.* *Self-rising flours* contain added sodium bicarbonate and an acid calcium salt in limited amounts to substitute for baking powder. *Phosphated flours* contain added mono-calcium phosphate only.

Besides these defined types of flours, the market provides specialized kinds adapted to particular uses which are not legally standardized. These include bread, all-purpose, pastry, and cake flours. *Bread flours* are strong flours usually made from the best hard wheats, or from blends of hard and soft wheats. They are high in protein, heavy in weight (112 grams or more per cup) and particularly adapted to bread making. Those considered choicest are patents, but some may be straights.

All-purpose or family-type flours are usually made from blends of hard and soft wheats, with more hard in the north where yeast

* See p. 538 for discussion of the nutritive advantages of enrichment.

breads are popular and more soft in the south where quick breads are used in greater quantities. They are somewhat lower in strength than true bread flours and weigh around 110 grams per cup. As the name indicates, they are suited to making most kinds of flour mixtures, though they do not produce the finest cakes or the spongiest loaves of bread.

Pastry flours generally are straight flours from soft wheat, weaker in strength and somewhat finer in granulation than the all-purpose type. They weigh 100 grams or less per cup. They are suitable for most flour mixtures other than yeast products or the finest cakes.

Cake flours are very finely ground, often very short patent, flours made from soft wheat. They may be specially bleached to whiten their color and soften their gluten. They weigh about 96 grams per cup and make the finest cakes, including those of unshortened kinds such as angel food.

Flours Other Than Those Made from Wheat

Rye flours resemble wheat flours in bread-making quality more than do those of any other cereal. Rye does not contain glutenin; hence the gluten it forms is not like that of wheat. Its gas retention is poor. Flours from other grains have little gas retention and in mixtures with wheat flour reduce its strength by dilution of the gluten. A small proportion of soybean flour or cooked potato may, however, be incorporated in bread without any detrimental effect. In other mixtures where high strength is not important, interesting variety can be obtained by including flours made from barley, buckwheat, corn, oats, potatoes, rice, and peanuts along with that from wheat.

THE APPRAISAL OF FLOURS

Nutritive Quality

It is now recognized that the adoption of roller milling about 1870 resulted in a profound change in the amount of vitamin B complex furnished by flour. Little is known about the white flours of earlier times except that they were produced by sifting wheat

ground in a stone mill. By using fine bolting cloth, flours of a high degree of extraction (as high as 55 per cent is recorded at the end of the eighteenth century) were obtained. We have no way of knowing what the vitamin content of these stone-ground white flours was except as we try to duplicate the process today. An investigation of this type revealed that a stone-ground flour of 55 per cent extraction possessed about 80 per cent as much thiamine as the original wheat.[33] This is attributed to the retention of the aleurone or inner bran layer which contains about one-third of the thiamine in the entire kernel. High-extraction roller milling removes this layer as well as the germ, which contains the highest concentration of the thiamine, and consequently modern white flour has a much reduced thiamine content. Not more than about one-fifth of the proportion in the whole grain is left in straight flours and only about one-seventh in patent flours. The aleurone layer and fine particles of bran in stone-milled flours contribute some color so that such flours are not so white as those produced by roller milling. It was this quality that led to the rapid adoption of the new process.

At the time that roller milling was introduced, however, the existence of nutritive essentials of the vitamin group was unsuspected. It is true that attention had been called to the superiority of whole-wheat over white flour on the basis of a general claim made by Dr. Sylvester Graham in his famous book on bread published in 1837 that "natural" foods were more healthful than refined. Although Graham's name has lived as a synonym for whole wheat, efforts to persuade the public to substitute whole-wheat for white bread and other white flour products have had little effect to this day. This has been true in spite of the greatly expanded scientific basis for the change, the recommendations of nutritionists over the last two decades, and the general availability of both whole-wheat flour and whole-wheat bread. Public taste continues to demand the palatability qualities of the white-flour products.

By 1940, evidence had accumulated about quantitative requirements for the vitamin B complex, especially thiamine, about the average amounts of thiamine consumed by most of the population in the United States, and about existing impairment of health resulting from thiamine deficiency, which led to deep concern on

[33] Schultz et al., *Cereal Chem.*, 19: 529 (1942).

the part of public health authorities. In a BHNHE study of diets of employed wage earners and clerical workers in cities, less than half the families were found to choose food which would provide the recommended amount of thiamine.[34] It is now recognized that the increase in sugar consumption which took place after the adoption of roller milling exaggerated the nutritional effect of the latter. Sugar, which contains no thiamine, and roller-milled white flour provided us with about 40 per cent of our calories but only about 8 per cent of the recommended amount of thiamine.[35] Altogether we consumed about half of our calories in the form of grain products and sugar. They furnished about one-eighth of the recommended amount of thiamine. If all the grain products were no more highly refined than old-fashioned white flour, they would have furnished two-thirds of the entire day's requirement for thiamine in a little less than one-third of the day's energy requirement, and, on the average, our existing pattern of consumption of other foods would have furnished the remaining third.

Roller-milled white flour also has a greatly reduced content of riboflavin and niacin. Patent flour contains about one-third as much riboflavin and about one-fifth as much niacin as the whole wheat. Likewise, the depletion of the iron to about one-fourth or less of the original amount strengthened the case for adopting measures which would make wheat products resume their former role in meeting our nutritional needs.

Few believed that the solution lay in persuading or in compelling, if that were possible, the use of whole-grain products. A 100 per cent whole-wheat bread has a compact texture and coarse grain which are unacceptable to most people. The remedy which was finally adopted was the addition of iron and synthetic vitamins of the B complex at the mill to white flours for retail sale. The official designation adopted for such flours was the term "enriched." During the years 1943–1946, enrichment of white, all-purpose, and bread flours (and white bread and rolls) was compulsory throughout the country as a war order. When this requirement was removed at the war's end, enrichment became voluntary except as the states adopted legislation requiring its continuation.

The practice of enrichment has brought dietary improvement proportional to the amount of such products consumed. Low-

[34] Stiebling and Phipard, *U. S. Dept. Agr., Circ.* 507 (1937).

[35] Lane et al., *J. Nutrition*, 23: 613 (1942).

income families, who eat relatively large amounts of grain products, received (in 1948) 14 per cent more iron, 20 per cent more thiamine, and 15 per cent more niacin than they would have without enrichment. Five southern states require enrichment of degermed corn meal, which is used there extensively in place of wheat flour.

The enrichment of flour and bread is generally approved and advocated by nutritionists and the medical profession. In stimulating public interest, however, caution is necessary to avoid creating the impression that enriched flour products are superior to whole wheat in food value, that they make perfect foods suitable for an unlimited role in the diet, or that substitution of them for other types of flour products ensures nutritional adequacy of the remainder of the food intake. (See Table LIX for the nutritive contributions of different types of flours.)

The nutritive quality of the proteins of whole wheat is also somewhat superior to that of proteins of the endosperm, but the difference is reduced by the decreased digestibility of protein produced by the high fiber content of the whole grain. It has been suggested that the optimum protein value of flour for man occurs in a flour of about 85 per cent extraction.[36]

Self-rising and phosphated flours carry an amount of calcium which adds significantly to the dietary content of this important mineral when flour consumption is relatively high. It has been estimated that the proportion of low-income families in the south getting less than two-thirds of the *Recommended Allowance* of calcium could be reduced from one-half to one-third simply by substituting a self-rising corn meal for the ordinary plain type.[37]

Digestibility

The completeness of digestion of flours is related primarily to their fiber content, which depends upon the degree of refinement. The high fiber content of whole grain products also slightly reduces protein digestion as already mentioned.

Sanitary Quality

Like breakfast foods, flour is too dry to encourage bacterial growth. In addition it is subjected to heating before being consumed. Hence it is seldom involved in health problems related to

[36] Dawbarn, *Nutr. Abstr. & Revs.*, 18: 691 (1949).
[37] Dickins, *J. Am. Dietet. Assoc.*, 29: 131 (1953).

Table LIX. The nutritive contributions of 100 grams (3½ ounces) of flours, given as percentages of the *Recommended Allowances* for a physically active man

[Babcock, *N. J. Agr. Expt. Sta. Bull.* 751 (1950)]

Food, measure and description	Energy	Protein	Calcium	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Ascorbic acid
	Food nutrients								
Wheat									
whole, hard wheat	11	19	4	27½	(0) *	36½	6½	28½	(0)
straight, hard wheat	12	17	2	11½	(0)	8	4	9½	(0)
straight, soft wheat	12	14	2	9	(0)	5½	3	8	(0)
80% extraction, hard wheat	12	17	2	11½	(0)	8	4	9½	(0)
patent, all-purpose	12	15	1½	6½	(0)	4	3	6	(0)
patent, enriched	12	15	1½	24	(0)	29½	14½	23½	(0)
patent, bread	12	17	1½	7½	(0)	5½	3½	6½	(0)
patent, enriched	12	17	1½	24	(0)	29½	14½	23½	(0)
cake or pastry	12	10½	1½	4	(0)	2	1½	4½	(0)
self-rising	11½	13	27	8½	(0)	5½	3	7½	(0)
self-rising, enriched	11½	13	27	24	(0)	29½	14½	23½	(0)
Rye									
light	12	13½	2	9	(0)	10	4	4	(0)
medium	11	16½	(2½)	21½	(0)	20	6½	16½	(0)
dark	10½	23½	5½	37½	(0)	40½	12	18	(0)
Corn meal									
degermed, unenriched	12	11½	½	9	6 †	9½	3	6½	(0)
degermed, enriched	12	11½	½	24	6 †	29½	14½	23½	(0)

* Imputed values in parentheses.
† Value for yellow. White only a trace.

this type of contamination, though it is subject to insect infestation and in individual lots is often condemned by the Food and Drug Administration for this reason.

Palatability

The palatability of flour is more appropriately evaluated in relation to its effect on the products made from it to be discussed later.

Economy

Flours differ markedly in price in the retail store. It might be expected that whole-grain types would be the cheapest because they involve the least processing and no loss in the sale of discarded portions for cheaper animal feeds. However, two factors—the relatively small amounts sold and their greater susceptibility to insect infestation and spoilage—cause them to be relatively more expensive than ordinary white flours. Among white flours, the special cake flours are usually the most costly because they are highly refined (short patent types) and expensively packaged. Bread flours tend to be more expensive than all-purpose types because they are made from hard wheats and are often of a shorter patent type. Pastry flours are usually the least expensive because they are made from soft-wheat flours. For greatest economy, they may well be chosen for all uses for which they are suited, which include most products other than those made with yeast or the finest cakes. However, any flour used in quantity should be "enriched," and most enrichment laws cover only bread and all-purpose flours. Hence, a nutrition-conscious consumer will choose a brand of pastry flour only after reading the label to see whether it has been voluntarily enriched.

SUMMARY OF POINTS TO CONSIDER IN SELECTING AND USING FLOURS

1. The primary considerations in choice of flours should be their nutritive values, baking qualities, and cost.
2. Whole-grain or enriched flours should be chosen for most uses.
3. Bread flours produce bread of uniformly high quality over the widest range of baking conditions but are relatively expensive.
4. All-purpose flours are satisfactory for all products except for the lightest, spongiest breads and the finest cakes.
5. Pastry flours can be used for all baking except yeast-leavened products and, if they are enriched, represent a good buy on account

of their relatively low price. They are not covered by enrichment laws, but some brands are voluntarily enriched.

6. Cake flours are the most expensive but preferable for the finest cakes.

PART E. *GENERAL PRINCIPLES AND PRACTICES IN THE SELECTION AND PREPARATION OF FLOUR MIXTURES*

The common ingredients of flour mixtures.
General technics in the manipulation of flour mixtures.
The baking of flour mixtures.
The storage of flour mixtures.
The appraisal of flour mixtures.
Dry flour mixes.
Summary of points to consider in selecting and using flour mixtures.

The economy of wheat flour and its culinary versatility have caused it to be employed as the foundation of a variety of food mixtures too numerous to be considered individually in this book. They resemble each other in possessing the structure of a foam in which gluten and starch, with or without the reenforcement of such other ingredients as egg, usually form the continuous phase entrapping dispersed gas. The gas may be water vapor, air, or carbon dioxide in different combinations and proportions, depending upon ingredients in the mixture and their manipulation. Aside from the flour itself, characteristic differences among the basic types of flour mixtures depend primarily upon the amount and kinds of other ingredients and the manipulation employed. (See Table LX for a comparison of proportions of other major ingredients used with a uniform amount of flour to make the more common types of mixtures.)

Successful preparation of flour mixtures is more dependent upon the following of carefully constructed recipes which include accurate measurements and definite directions for procedure than that of almost any other class of food. In general, the palatability of all flour mixtures depends upon (1) the kinds and proportions of ingredients, (2) their manipulation, (3) the conditions of baking, and (4) the conditions of storage and length of the holding period after baking.

Table LX. Proportions of ingredients other than leavening used with one cup of flour in different flour mixtures

[After King and Freeman]

Flour mixture	Liquid, tablespoons	Eggs, number	Fat, tablespoons	Sugar, tablespoons
Bread:				
hard-wheat flour	5		1/4	1/4
soft-wheat flour	4		1/5	1/3
Biscuit	5 1/3		2	0
Pastry	1 2/3		4	0
Muffins	8	1/2	1–2	1/2–1
Griddle cakes	10 2/3	2/3	1 1/3	0
Popovers	16	2	1	0
Foundation cake	5 1/3	2/3	2 2/3	8
Sponge cake	0	4–5	0	16
Drop cookies	3	1/2	3	6
Roll cookies	0–1	1/2	4	8

THE COMMON INGREDIENTS OF FLOUR MIXTURES

The ingredients of most importance in determining the basic structure of flour mixtures are the flour, liquid, leavening agent, shortening, and egg and sugar if they are present.

The Flour

In individual recipes, the proportions of ingredients, and, to some extent, the amount of manipulation that is desirable are dependent upon the kind of flour used. The most important differences among flours which affect their behavior in a mixture are their capacity to absorb water and their gluten strength. As previously explained (see Part D), flours differ in their moisture-absorbing capacity, that is, in the amount of water that can be incorporated without disrupting the continuous gluten structure. If such a structure is to be maintained, the films of water adsorbed on the surfaces of the protein micelles may not exceed a certain thickness.

The moisture-absorbing capacity of most flours ranges from 50 to 65 per cent by weight. Mixtures which do not exceed the capacity of the gluten to stick together when handled on a board are called doughs; those too moist to meet this specification are known as batters and may be further subdivided into the type thin enough to pour readily, known as pour batters, and those which break as

an attempt is made to pour them, known as drop batters. Cookies and pastry are stiff doughs; rolled biscuits, yeast bread, and rolls are soft doughs. Drop biscuits, drop cookies, and muffins are drop batters, and cakes, griddle cakes, waffles, and popovers are pour batters.

The moisture-absorbing capacity of a flour is related to its weight, a heavy flour absorbing more than a lighter one. For this reason, weight is a more accurate measure of the amount of flour required to give a uniform product with a particular recipe than is volume. (See Part D for weights per cup of the different types of flour.)

Differences in gluten strength can be compensated by adjusting the proportion of shortening because shortening reduces strength. For this reason, recipes for shortened cakes are more easily adjusted to different types of flour than unshortened, and recipes for loaf and pound cakes, which contain relatively large proportions of shortening, can more readily be adjusted to use with strong flours than can recipes for cakes containing little or no shortening. The action of shortening in relation to gluten strength is particularly noticeable in pastry. When pie crust is made under standardized conditions, its tenderness varies approximately with the protein content of the flour. With a uniform amount of shortening, low-protein (7.5 to 8 per cent) cake and pastry flours give the lowest breaking strength, which means greatest tenderness; all-purpose or family flours (protein averaging 10 per cent) give medium breaking strength; and high protein (about 14 per cent) bread flours result in the highest breaking strength. To obtain a tender pastry with bread flour it is necessary to employ a relatively high proportion of shortening. However, flakiness in texture, which is preferred by many, is associated with the moderate degree of tenderness produced by an all-purpose flour with an intermediate amount of shortening.

Commercial bakers cannot afford a wide range of variation in their products, such as is comparatively unimportant in the household. They test their flour for moisture-absorbing capacity and alter the entire recipe accordingly. When they use the stronger flours in cakes and cookies, they attempt to maintain a standard product by decreasing the proportion of egg and increasing that of sugar and shortening. In making pastry, they vary the proportion of fat to fit the strength of the flour, because, as stated previously, stronger flours require more shortening to give a tender product.

Tests show that the fact that a flour makes a good product in one recipe is no guarantee that it will do so in another. Household methods of adjusting recipes to differences in flour are more crude and hence may give less satisfactory products than those demanded by a commercial baker. For example, it is common household practice to measure all other ingredients comparatively carefully and then vary the quantity of flour according to its moisture-absorbing capacity as indicated by the consistency of the batter or dough. This changes all other proportions in the mixture and consequently may not give satisfactory results. When a relatively strong flour is used in cakemaking, a fraction of cornstarch may be substituted for an equal amount of flour to increase tenderness in the product. This again is not a very exact method of modification.

The Liquid

In addition to its role of developing gluten, liquid also dissolves sugar, hydrates egg proteins, initiates the reaction of chemical leaveners and enzymes, promotes yeast growth, and, during heating, facilitates the gelatinization of starch. Milk is a preferred liquid, both because it adds to food value and because it contributes to browning during baking. Evaporated and dried milks are well-adapted to use in flour mixtures.

Leavening Agents

The leavening of flour mixtures is accomplished by the expansion of the incorporated air and by the internal production and expansion of water vapor and carbon dioxide. Air and water are always present; when the product is heated, the air expands and part of the water vaporizes. Carbon dioxide formation requires the presence of suitable microorganisms or chemical agents. In both methods, production of the gas is accelerated during the first part of the heating period, and such gas as is formed expands as the temperature rises.

Air as a Leavening Agent

Air is incorporated in flour mixtures mechanically by sifting flour, creaming shortening, beating eggs, or by beating the mixture itself. In the form of beaten egg white, it gives light, spongy prod-

ucts often containing rather large gas cells. When beaten into a dough, as in beaten biscuits, air gives comparatively small increase in volume but fine grain in the product.

Water Vapor as a Leavening Agent

Water vapor is formed in quantities sufficient to leaven the mixture when liquid and flour are present in equal volumes. This is the approximate relationship in popovers and results in their characteristic hollow centers, moist interiors, and large volume.

Carbon Dioxide as a Leavening Agent

Carbon dioxide is produced either from sugar by yeast or from a carbonate, usually sodium bicarbonate, by action of an acid.

Yeast and the Production of Carbon Dioxide

Yeasts are microscopic, unicellular plants which multiply rapidly under suitable conditions and obtain energy by breaking down sugars to carbon dioxide and alcohol. The process is known as fermentation and is promoted by the enzyme (or enzymes) *zymase* contained in the yeast. Yeasts also produce enzymes which are able to split disaccharide sugars.

If carbon dioxide is to be produced in adequate amounts for leavening, conditions must be suitable for continuous rapid multiplication of the yeast. One of the essentials is proper food. Yeast requires nitrogenous compounds, minerals, fermentable sugars such as sucrose, maltose, glucose, or fructose, and certain vitamins. These nutrients must be present in sufficient quantities or satisfactory leavening is impossible.

The yeast nutrient most frequently deficient in flour mixtures is probably sugar, of which flour itself contains only 1.5 per cent. Sugar serves at least three functions in making bread and other yeast-leavened products: (1) it is broken down to form carbon dioxide, (2) enough must remain to give the slightly sweet taste desired, and (3) it contributes to the browning of the crust.

There are three sources of sugar available to the yeast in a typical dough—that added as an ingredient, that present in the flour, and that formed from starch in the flour. Flour contains two enzymes (amylases) which hydrolyze part of the starch when conditions of moisture and temperature are favorable. One of the amylases,

known as *beta-amylase*, completely hydrolyzes amylose to maltose and partially hydrolyzes amylopectin to maltose, leaving residual dextrins at the points of branching of the latter. The other amylase, *alpha-amylase*, hydrolyzes amylose and amylopectin to dextrins which are in turn broken down to maltose and glucose (the latter to a limited extent) by further action of both enzymes.

The series of biochemical changes that develop in a fermenting dough and result in leavening may be outlined as follows:

(*a*) Production of maltose (and some glucose) from starch by amylases.

$$\text{Starch} \xrightarrow[\text{(amylases)}]{} \text{maltose (and glucose)}$$

(*b*) Production of CO_2 from sugars by yeast.

$$\text{Maltose} \xrightarrow[\text{(maltase)}]{} \text{glucose} \xrightarrow[\text{(zymase)}]{} \text{alcohol plus carbon dioxide}$$

Maltase, as well as zymase, is contained in the yeast.

The capacity of flour to serve as a food for yeast growth and thus to influence carbon dioxide production (sometimes called its gassing power) is more dependent upon its amylolytic activity than upon its original sugar content. Flours differ in amylolytic activity. Deficient activity may be a result of the presence of a less than optimum amount of alpha-amylase or of starch highly resistant to enzyme action. It is now thought that all sound starch granules resist enzyme action until they are partly gelatinized during baking, but starch granules damaged in grinding are susceptible to attack. Hence, the larger the proportion thus altered in milling, the greater is the sugar production before baking. In the household, cooked potato, potato flour, and scalded flour, which are sometimes added to yeast doughs, stimulate fermentation because of their content of gelatinized starch.

Conditions of wheat growth influence the amount of amylases present in flour. For example, sprouting of the wheat increases the amount of alpha-amylase, thus accounting for the high amylolytic activity of malt. Sound, ungerminated grain contains relatively large amounts of beta-amylase and only small quantities of alpha-amylase.

Formerly, *dried yeast* was a mixture of yeast with corn meal or starch, pressed into cakes and dried. Such yeasts continue to live but are in an inactive state. When furnished with food and moisture, they begin to develop and multiply but do so slowly. They need to be soaked in lukewarm water and mixed with very soft dough

(sponge) for a preliminary period of development before all the other ingredients are added. They have the advantage of keeping a comparatively long time and of being inexpensive.

Activated dry yeast is the type now available. It develops much more rapidly than ordinary dried yeast and is less perishable than compressed yeast. It does not require activation in a sponge but can be used in straight-dough mixing. Activated dry yeast is a more expensive product than the older type. Both types of dry yeast retain their activity longer at refrigerator temperatures than at room temperatures.

Compressed yeast is a moist mixture of yeast plants and starch. The yeast remains active and will begin to grow and multiply with great speed when it is added to a dough and held under proper temperatures. Its cost is about the same as that of activated dry yeast but it keeps well for only a few days at refrigerator temperatures. If held in the freezing compartment, however, it retains its activity for several weeks or even months.

Liquid yeasts and *starters* are sometimes used in household breadmaking. They are mixtures of active yeasts, which may have been secured from either compressed or dried forms, with yeast foods such as sugar and potato water or dough. They may be kept from one baking to the next, and have the advantages of being cheap and of working rapidly. These yeasts should be replaced frequently with a new commercial product because they are readily contaminated with wild yeasts which give bread undesirable flavors.

An early type of leavened bread was called salt-rising bread. In this kind of bread, the gas was produced by bacteria present in the ingredients (the species *Bacillus welchii,* for example) which were cultivated in a sponge of flour, corn meal, salt, and milk. When the mass became porous, flour was added to make a dough, and, after further rising, this was baked. Spontaneous fermentation of this sort, in which wild forms of bacteria are depended upon, lacks uniformity, and modern salt-rising bread is usually made with a commercial salt-rising "yeast," which is a cultured form of appropriate bacteria.

In the household, choice of a yeast may be based on relative cost, storage requirements, length of life, and the relative convenience of active types versus the types that require activation—differences that have been explained above. Yeasts have a high content of vitamins of the B complex, but the amount contributed to products leavened in this way is not particularly significant. When nutritionists refer

to the high value of yeast for these nutrients and protein, they are referring to dried brewer's yeast, a powdered form of dead yeasts which may be included in food-mixtures in amounts that are highly supplementary.[38] Live yeasts, the form in yeast cakes, are not digested; hence their nutritive values are unavailable, contrary to frequent advertising claims.[39]

Production of Carbon Dioxide from Sodium Bicarbonate

When sodium bicarbonate is heated, it gives off part of its carbon dioxide, but leaves sodium carbonate as a residue. This compound is objectionable in taste and hence should always be neutralized with an acid which leaves a relatively tasteless and harmless salt. In household cookery, the acids used include the lactic acid in sour milk or buttermilk, the acids in molasses, and cream of tartar. The amount of sour milk required to neutralize a given quantity of sodium bicarbonate depends, of course, upon its degree of acidity, which is variable. The proportions commonly used are ½ teaspoon of soda to 1 cup of average sour milk.* Sodium lactate is the residue of this reaction. Molasses also varies in acidity, but ½ teaspoon of soda per cup is suitable for the average commercial product. About 1⅛ teaspoons of cream of tartar (potassium acid tartrate) neutralizes ½ teaspoon of baking soda. The residue is sodium potassium tartrate, also known as Rochelle salts. There is no practical household method of ensuring a uniform hydrogen-ion concentration when soda is used in combination with the acids mentioned above. In general, however, on account of the detrimental effect of alkalinity on flavor and thiamine retention, it is better to err in the direction of too little soda rather than too much.

In certain flour mixtures, variations from neutrality produce effects that are deliberately sought by altering the reaction of the dough in one direction or the other with unneutralized baking soda or cream of tartar. In devil's food cake, for example, a neutral dough gives a browner product, whereas alkalinity gives the rich mahogany color that many people prefer. The reaction of the dough likewise affects the color of molasses cookies. When no sodium bicarbonate is added, the cookies are pale in color; when it is added,

38 Brenner et al., *J. Am. Dietet. Assoc.*, 25: 409 (1949).

39 Parsons and Collord, *J. Am. Dietet. Assoc.*, 18: 805 (1942). Von Loesecke, *J. Am. Dietet. Assoc.*, 22: 485 (1946).

* Adding one tablespoon of lemon juice or vinegar to sweet milk makes a product approximating sour milk.

the intensity of color increases with the quantity of soda. Flavor is also affected, that of the molasses being too pronounced in the acid cookies, whereas that of alkali becomes objectionable as the quantity of soda increases. The cream of tartar recommended for angel food cakes increases their acidity and tends to make them white and fine-grained; they are coarser grained and yellowish without it. The effect on color is a result of action on flour pigments which are yellow in alkaline solution but colorless in slightly acid solution.

The most accurate way for the homemaker to obtain a uniform residue and dough reaction from sodium bicarbonate is to employ commercial baking powders. These are mixtures of baking soda with some suitable acid, diluted with cornstarch to give a product having the desired gas strength. Food laws specify a capacity to produce at least 12 per cent of carbon dioxide by weight, but most household baking powders yield about 14 per cent. The cornstarch also serves to separate the acid and the base, thereby increasing the stability of the mixture during holding in the can. Four teaspoons of baking powder equal approximately 1 teaspoon of soda in carbon dioxide yield.

Baking powders vary in properties with the acid which they contain. Tartaric acid and its acid salts, the acid salts of phosphoric acid, and sodium aluminum sulfate, the latter usually in mixture with a phosphate and called a "combination" baking powder, are used. The probable reactions and residues from each are indicated by the following equations:

$$KHC_4H_4O_6 + NaHCO_3 = KNaC_4H_4O_6 + CO_2 + H_2O$$

Cream of tartar plus sodium bicarbonate gives potassium sodium tartrate plus carbon dioxide and water.

$$H_2C_4H_4O_6 + 2NaHCO_3 = Na_2C_4H_4O_6 + 2CO_2 + 2H_2O$$

Tartaric acid plus sodium bicarbonate gives sodium tartrate plus carbon dioxide and water.

$$3CaH_4(PO_4)_2 + 8NaHCO_3 = Ca_3(PO_4)_2 + 4Na_2HPO_4 + 8CO_2 + 8H_2O$$

Calcium acid phosphate plus sodium bicarbonate gives tricalcium phosphate plus disodium phosphate plus carbon dioxide and water.

The reactions in a combination baking powder are complicated by interaction between the phosphate and sodium aluminum sulfate (often abbreviated to S.A.S.) as well as between each and the soda. A type of baking powder popular with commercial and institutional bakers contains sodium acid pyrophosphate as the acid. It yields about 17 per cent carbon dioxide, an amount considered preferable for quantity cooking, but it must be measured carefully because even a slight excess of residue imparts an undesirable aftertaste to the product.

Although most of the ingredients in flour mixtures affect the *p*H of the product either through their buffering action or through their individual reaction, chemical leavening agents have the most pronounced effect. In earlier studies of the reaction of cakes and biscuits, it was found that, the larger the proportion of baking powder used, the more alkaline the products became—indicating that the proportion of bicarbonate in the baking powder was more than enough to neutralize the acid in the mixture. So far as flavor was concerned, the optimum *p*H for white and yellow cakes was judged to be 7.22 to 7.35, and those outside the range 7.0 to 7.9 were considered distinctly inferior.[40] More recently, in biscuits it was found that increasing the proportion of baking powder 50 per cent above the manufacturer's recommendation resulted in only a slight degree of alkalinity.[41]

In addition to the effect of hydrogen-ion concentration in flour mixtures on their palatability qualities, we are now aware of and concerned with its effect on nutritive quality, especially thiamine retention. An alkaline reaction causes relatively high losses as will be discussed in more detail later.

In the Southern states much of the soft-wheat flour is "phosphated," that is, it contains mono-calcium phosphate which has been added at the mill in the proportion of one-fourth to three-fourths of 1 per cent of the weight of the flour. In that section of the country most of such flour is eaten in the form of biscuits made with buttermilk or sour milk. Because the usual recipes specify amounts of soda in excess of that neutralized by the acid in the milk, addition of the phosphate to the flour improves the volume, grain, and color of the biscuits. This amount of phosphate does not interfere with the quality of the biscuits made with sweet milk, and it also has a favorable effect upon the palatability of yeast bread when the flour is used for that purpose. Although it is a source of calcium and phosphorus which may be utilized by the body, the amount consumed in this form would not be a significant share of the requirement except when flour consumption is relatively high.

Self-rising flours contain the complete chemical leavening and salt for seasoning. The leavening chemicals consist of a mixture of sodium bicarbonate and acid phosphate.

[40] Barackman, *Cereal Chem.*, 19: 121 (1942). Stamberg and Bailey, *Cereal Chem.*, 16: 419 (1939).

[41] Briant and Hutchins, *Cereal Chem.*, 23: 512 (1946).

The fineness of division of the sodium bicarbonate in a baking powder is of interest to the cook because coarse particles may produce brown spots. These spots have been attributed to slow solution of coarse Na_2CO_3 and its action on the flour pigments. It has been shown, however, that when phosphate powders are used, coarsely ground primary calcium phosphate may produce brown or yellow dextrins from the surrounding starch. In any event, the difficulty can be minimized by distributing the baking powder well before adding the liquid, or by allowing the dough to stand about 15 minutes before baking to give more time for solution. The grain of the baked product may also be affected by the relative fineness of the baking powder as a whole, smaller particles tending to produce smaller gas bubbles and therefore a finer grain.

So far as existing knowledge is concerned, consumer interest in the type of acid used in baking powder rests on its relation to cost, activity in the cold dough or batter, effect on gluten and other components, and the wholesomeness of the residues. The combination and phosphate baking powders are usually sold at half the price of the tartrate type or even less. Cream of tartar and tartaric acid are relatively expensive.

The rate of reaction between the acid and the base, which begins as soon as moisture is added to the mixture, varies with the kind of acid and the temperature of the ingredients. The user is interested in the proportion of the gas which is liberated at room temperature, because this is a factor in the losses of gas occurring during manipulation and standing, and in the choice of oven temperature. In batters of the muffin type which are at room temperature, tartrate baking powders release more than half of their carbon dioxide in 40 seconds of mixing, but the combination type releases less than one-third.[42] In cold biscuit dough, it has been found that in 15 minutes about two-thirds of the sodium bicarbonate is decomposed when cream of tartar or calcium acid phosphate is the acid used, and only about two-fifths with a combination of phosphate and S.A.S. About three-fourths of the gas liberated during the mixing of doughs is lost.[43]

Relatively little gas is lost after mixing is discontinued, but obviously the time spent in mixing, the vigor of the mixing, and the length of the period of standing before baking limit the amount of

[42] Noble and Halliday, *Cereal Chem.*, 8: 165 (1931).

[43] Barackman, *Cereal Chem.*, 8: 423 (1931).

gas left to increase dough volume. When the quick-acting tartrate and phosphate * powders are used, it is necessary to mix rapidly and skillfully, and the period of standing before baking should be relatively short. Because prebaking losses of gas are less, smaller quantities of the combination-type baking powder suffice. In general, 1 to 2 teaspoons of baking powder are recommended for each cup of flour. One teaspoon of the combination type is sufficient under most conditions.

The temperature at which the baking powder begins to react is a factor in the choice of oven temperatures. Doughs made with combination baking powders may be placed in cooler ovens to good advantage because this allows time for maximum expansion before coagulation.

The effects which the baking-powder components produce on the various dough ingredients have not been investigated extensively. There may be other differences which we cannot now recognize. At present, we may consider them unimportant in affecting choice of a baking powder.

All baking powders except the calcium phosphate type leave residues, concerning the harmfulness of which there has been much controversy. The powders containing sodium aluminum sulfate have been subjected to the most criticism. In one study of the effect of the three types of baking powders on growth and kidney function of rats, no difference between the groups receiving the powders and the controls could be detected. Although the amount of baking powder included in the diets was twice that found in ordinary doughs and the experiment was continued through two generations, there was no detectable toxic or injurious action.[44] Aluminum when consumed in any form—in baking powders, dissolved from utensils, or naturally present in plant materials—has been shown to be almost entirely excreted in the feces and hence not absorbed in significant amounts. All baking-powder residues have a laxative action when taken in sufficient quantities.

The calcium phosphates in the phosphate and double-acting types of baking powders contribute to the body requirements for these minerals, but, in view of the amounts in which chemically leavened mixtures are ordinarily eaten, this is not an important consideration.

* One of the common brands of phosphate baking powder is now designated "double acting" because part of the calcium phosphate has been made slow-acting by a special heat treatment. Sodium pyrophosphate powders are also slow-acting.

[44] Rose and Catherwood, *J. Nutrition*, 2: 155 (1929).

The suggestion has been made that calcium carbonate might be used as a filler in all baking powders instead of starch and thus substantially increase the contribution of calcium.[45] However, direct addition of calcium salts to flour would be a more effective way of supplementing milk as a source of this important mineral, because yeast-leavened products would then be involved as well as those in which baking powder is used.

In conclusion, present evidence indicates that choice of a baking powder might well be on the basis of relative cost and effectiveness of leavening under ordinary conditions of use. Perhaps the latter is not affected to an important degree by reactivity in the cold mixture when the cook is experienced. Satisfactory results can be obtained with any type, though uniformity of products may be greater when one type is used consistently. Double-acting kinds can be reasonably expected to give better products for the inexperienced cook and are recommended for use in cakes in which the shortening is distributed by beating instead of creaming. They have the disadvantage of affecting flavor adversely when used in overmeasured amounts.

The Shortening

The major structural roles of shortening in the preparation of flour mixtures are increasing tenderness and aiding in leavening. In cake batters, shortening by its firmness also adds mechanical strength to the batter, reducing the tendency of the batter to fall of its own weight before the heat of baking coagulates the gluten and egg structure and gelatinizes the starch.[46]

The capacity of fats to coat flour particles and remain in solid layers separating other ingredients interferes with continuous gluten formation. As a result, the cooked product has properties of tenderness which have been defined in terms of crushing and breaking strength. The relative capacity of a fat or oil to contribute low crushing and breaking strengths in a flour mixture is known as its *shortening power*. Besides tenderness, fat, more readily than oil, may produce flakiness when it is distributed in thin sheets between layers of flour. This is a desired characteristic of pie crust.

Shortening power depends upon inherent properties of the fat and the conditions under which it is used. So far as the nature of

[45] Melnick et al., *J. Am. Dietet. Assoc.*, 21: 611 (1945).

[46] Pyler, *Baking Science and Technology*, Siebel Publishing Co., Chicago, 1952, Vol. I, p. 299.

the fat itself is concerned, important characteristics are its plasticity (or consistency) and its emulsifiability. Those fats which soften most during incorporation in a dough have been found to form the tenderest, but not the most flaky, pastries.[47] Probably this is a result of the formation of comparatively large areas of fatty films which coat and separate the flour particles.

Oils and melted fats are, of course, not plastic. Their shortening power probably resides in the *polar groups* (glycerol end and unsaturated linkages) of their molecules which are attracted to moistened flour particles and obstruct contacts which would otherwise form a continuous gluten structure. Because oils tend to remain in droplet form, they are less effective shorteners than plastic fats. Also, they do not "cream" and cannot carry air to add to the leavening of a mixture. As might be expected, pie crust made with oil or melted fat is not likely to be flaky, although under certain conditions it may be.

In pie crust and biscuits where the proportion of liquid is small, the major portion of a solid shortening coats flour particles and forms thin sheets between layers of flour. In cakes and most other mixtures which contain a larger proportion of liquid, the shortening is more or less emulsified. Oils and melted fats can be dispersed by stirring but ordinary fats require creaming with the sugar to distribute them. The most tender and velvety cakes appear to be those in which a water-in-fat emulsion is formed. The creaming process softens the fat to produce such an emulsion.

Adding emulsifiers makes it possible to distribute the shortening by simple beating with other ingredients without a preliminary creaming with sugar. Another advantage of the addition of an emulsifier is the possibility of using cake recipes containing relatively high proportions of sugar, milk, and egg. Such cakes are moist, soft, less expensive, and lower in calorie value than those high in fat. The emusifiers used in "cake-conditioned" shortenings are generally the mono- and diglycerides mentioned in connection with superglycerination (see Chapter 13), but new and even more effective substances are being investigated. The addition of emulsifiers probably increases the capacity of a shortening to form an emulsion rather than to coat the flour.

Another cause of differences in shortening power among shortenings is the variation in the proportion of fat which they contain.

[47] Hornstein et al., *Food Res.*, 8: 1 (1943).

Butter and margarine legally contain a minimum of 80 per cent fat, the remainder being water, salt, milk, protein, etc., substances which possess no shortening power. Weight for weight, the commercial hydrogenated shortenings contain the same amount of fat as the 100-per-cent-fat shortenings such as lard, but on a volume basis the air which has been incorporated in them diminishes their relative shortening value.

Such batters as those for cakes are so highly diluted by the liquid, eggs, and sugar that the solid fat component with its volume expanded by air gives them considerable mechanical strength. As stated previously, this stabilizing effect reduces the tendency of the cake to fall of its own weight.

In spite of the differences among shortenings that can be demonstrated under controlled conditions, so many variables enter into the average conditions of household preparation of mixtures containing them that products which are satisfactory by ordinary standards may be produced from any type. It should be remembered that shortening power is by definition the relative capacity of a given amount of fat to contribute tenderness. If enough is used, differences among shortenings disappear. However, the discriminating cook knows that there is no all-purpose shortening equally desirable for all products, even under household conditions. See Chapter 13 for an appraisal of common shortenings from the standpoint of household use.

Eggs

Eggs perform several important functions in flour mixtures. When whipped, they incorporate air and in cakes are capable of leavening five or six times their weight of other ingredients. They help distribute shortening by means of their emulsifying power. Owing to their fat content (one-third of the yolk is fat), they have some shortening action. No substitute has been found for the flavor that they contribute, and the dominating color of the yolks is highly prized in many products. Eggs add to the capacity of the mixture to develop a structure to retain gas, and at the same time they exert a binding and thickening action. They retard evaporation from baked products and thereby delay staling.

Factors affecting the whipping quality of egg whites are discussed in Chapter 13. For cakemaking in particular, fresh, storage, or frozen eggs are preferable to dried eggs on account of their higher

foaming capacity, but individual fresh eggs differ in their cake-making qualities. Frozen eggs appear to be satisfactory substitutes for fresh or storage eggs in flour mixtures and are extensively used in commercial baking.

Sugar

The sugar in flour mixtures is more or less completely dissolved in the liquid. Structurally, its principal effect is to reduce gluten strength and contribute to certain texture effects, such as tenderness, closeness of grain, or crispness, depending upon the other ingredients. When it is creamed with the fat, the size of the crystals affects creaming volume and grain. Fruit-powdered granulated sugar may be superior to the larger standard crystals because it produces a finer dispersion of the shortening. Coarser granulation gives a coarser grain to cakes, and powdered sugar is believed to be inferior because the grinding to which it has been subjected leaves rounded edges which reduce their effectiveness.

Sugar also contributes sweetness and capacity to develop a brown color during baking.

GENERAL TECHNICS IN THE MANIPULATION OF FLOUR MIXTURES

The mixing, beating, folding, and other manipulations of flour mixtures perform the primary function of distributing the ingredients uniformly. In yeast-leavened products, fairly vigorous manipulation is required to develop the gluten (with hand-mixing there is not much danger of overmanipulation), but, when sodium bicarbonate is the source of leavening gas, it is essential in most cases that mixing be accomplished with limited stirring, once the liquid has been added. Otherwise, losses of carbon dioxide may be excessive. Overmixing cake batters, for example, gives products with comparatively low volume and compact texture. The optimum kinds and amounts of mixing vary with the type of product desired, the character of the ingredients used, temperature of the ingredients, and the method of agitation. Unrecognizable differences in handling technics alter results and make it very difficult to standardize the preparation of all flour mixtures.

The principal problems involved in the manipulation of most flour mixtures other than yeast-leavened products are (1) securing a

uniform distribution of the moisture with a minimum loss of carbon dioxide, (2) securing a uniform distribution of the fat in particles of appropriate size, (3) incorporating the foam structure of beaten egg with a minimum loss of air.

Securing a Uniform Distribution of the Moisture with a Minimum Loss of Carbon Dioxide

It is particularly difficult to distribute the water in doughs so that each flour particle is as moist as the others. In preparing biscuit dough by hand mixing, a short kneading period is recommended for this purpose. The problem in pastry making, where the percentage of water is suitable for gluten formation, is to form only enough gluten to give adequate cohesion for handling, a condition which results in desired tenderness. Sprinkling the water over small fractions of the flour-fat mixture, such as the amount required for one crust, facilitates mixing with the least amount of gluten development.

In preparing a more moist flour mixture such as for muffins, mixing must be carefully limited to prevent overdevelopment of gluten, which causes tunnels, irregularly shaped tops, and decreased volume. The amount of beating that can be tolerated is also related to the type of baking powder. In preparing certain cake mixtures, Halliday found that those containing a phosphate baking powder began to get heavy if beaten more than 1 minute, and those containing a tartrate powder if beaten more than 2 minutes, whereas those containing a combination powder were best when beaten 10 minutes.[48] Sifting dry ingredients causes the particles to become surrounded with films of air and assists their dispersion in water.

Securing a Uniform Distribution of the Fat in Particles of Appropriate Size

Because the shortening is the single component of flour mixtures which does not disperse readily in water, the problem of its distribution becomes dominant in the mixing of many batters and doughs. Its dispersal is affected by such factors as the kinds and amounts of manipulation or methods of combining it with other ingredients, the nature of the other ingredients, and the temperature of the ingredients, including the shortening, at the time of

[48] Halliday, *J. Home Econ.*, 12: 42 (1920).

manipulation. Examples of these effects will be mentioned in the discussion of typical flour mixtures. (See Part F.)

Melted fats and oils may be simply stirred into dry ingredients along with other liquids. This method is employed in making muffins and may be used for cakes. The liquid fats are distributed in relatively large droplets by this method, and it is, in general, suitable only for products to be consumed shortly after baking. The presence of egg may improve the dispersion because of its emulsifying properties.

When a solid shortening is used, it may be dispersed by first mixing it with a dry ingredient, such as the flour in pastry or baking powder biscuits, or the sugar in cakes. In the conventional method of mixing a shortened cake, the fat and sugar are well-creamed, after which the wet and the other dry ingredients are added in alternate fractions. By this means, it is possible to disperse the fat in relatively small particles and at the same time to incorporate air as mentioned above.

Creamed fats produce cakes which have a texture superior to that of cakes made with oil or melted shortening. Whipping shortening during manufacture to improve plasticity also incorporates air and reduces the labor of hand creaming in the household. The air bubbles apparently form the nuclei to which water vapor and carbon dioxide are added as they evolve. It has been observed, in cakes at least, that these gases form few if any new gas cells but collect at the air bubble interfaces and increase their volume.[49] Hence sufficient creaming and dispersion of the creamed fat are very important in relation to effective leavening and uniformity of texture in the final product.

New-type shortenings, however, which contain an emulsifier, can be readily distributed in wet mixtures by beating. But, in general, breaking up the fat by creaming it thoroughly with the sugar distributes it more evenly than other methods of mixing.

THE BAKING OF FLOUR MIXTURES

The changes that occur during the baking of flour mixtures include (1) the production of steam and carbon dioxide and expansion of all the leavening gases including air, (2) the coagulation of

[49] Carlin, *Cereal Chem.*, 21: 189 (1944). Dunn and White, *Cereal Chem.*, 16: 93 (1939).

egg and gluten, (3) the gelatinization of the starch, which is much more complete in batters than in doughs that lack sufficient water, (4) the melting of the fat, (5) the loss of water which is highest on the surface and tends to form a crust, and (6) the solution of any undissolved sugar and the reaction between it and amino groups which give a brown color in crusts. A small amount of caramelization may enter into this color change, but it has been maintained that the temperature does not go high enough for much of this type of decomposition.[50]

Internal temperatures in such flour mixtures as biscuits, muffins, shortened loaf cake, and angel cake have been found to reach 208 to 212 degrees F. (97 to 100 degrees C.) during baking at low altitudes.[51] They are probably lower at higher altitudes. Crisper products, such as waffles and wafers, or the crusts of the products listed above, reach 300 degrees F. (149 degrees C.).[52] Internal temperatures during baking are also affected by the nature of the material from which the pan is made.[53]

The oven temperatures recommended for baking flour mixtures depend upon the nature of the ingredients and the size and shape of the unit of dough. When flour mixtures contain large proportions of sugar, temperatures must be relatively low to prevent excessive browning and, in some cases, burning. With all flour mixtures, oven temperatures should be such that the outer layer is not coagulated before optimum leavening has taken place. Premature coagulation of the outer layer causes flatness and heaviness in the product and a broken, uneven top if the gas is still being produced at a rate sufficient to develop pressure enough to break the surface at its weakest point. The rate of heat penetration is related to oven temperature and the size and shape of the dough units. Small masses of dough require comparatively short periods of time to heat to the center and may therefore be cooked quickly at high temperatures, whereas larger units should be baked at lower temperatures. In ovens regulated by a thermostat, the degree of uniformity may need to be considered in the selection of the oven temperature. If the thermostat allows a range of 50 degrees F. or more, it may be better to set it rather low for some products. When oven walls are thin

[50] Baker et al., *Cereal Chem.*, 30: 22 (1953).

[51] Hall, *Cereal Chem.*, 7: 270 (1930). Woodruff and Nicoli, *Cereal Chem.*, 8: 243 (1931). Denton and Johnson, *J. Home Econ.*, 24: 927 (1932).

[52] Barackman and Bell, *Cereal Chem.*, 15: 841 (1938).

[53] Reed et al., *J. Home Econ.*, 29: 188 (1937).

and insulation is poor, somewhat higher temperatures than those appropriate with a well-insulated oven are suitable.

Often there may be several methods of getting equally satisfactory results in baking. Experiments comparing flour mixtures baked by starting in a cold oven with those baked in preheated ovens of gas, electric, and kerosene stoves show that there is in some cases little difference. Plain and angel food cakes were always superior when baked in preheated ovens at the temperatures employed in one test. Biscuits were equally desirable with both methods except in electric ranges where preheating was preferable.[64] Differences in fuel consumption were considered negligible.

Table LXI shows the baking temperatures recommended for a number of flour mixtures.

Table LXI. Oven temperatures recommended for flour mixtures *, †

Type of product	Approximate time required for baking, minutes	Oven temperature	
		Degrees F.	Degrees C.
Breads			
biscuits	10 to 15	425 to 450	218 to 232
cornbread	30 to 35	400	204
muffins	20 to 25	400 to 425	204 to 218
popovers	45	450 for 15 min., then 350 for 30 min.	232 for 15 min., then 176 for 30 min.
yeast bread	30 to 40	400	204
yeast rolls	15 to 25	400 to 425	204 to 218
Cakes, with fat			
cup	15 to 25	375	190
layer	25 to 40	375	190
loaf	45 to 60	350	176
Cakes, without fat			
sponge and angel	45 to 60	300 to 350	149 to 177
Cookies			
drop	10 to 15	350 to 400	176 to 204
rolled	8 to 10	375	190
Pastry			
one-crust pie (custard type)	20	450 for 15 min., then 350 to finish	232 for 15 min., then 176 to finish
prebaked shell	25 to 30	350	176
shells	8 to 10	450	232
two-crust pies	30 to 50	425	218

* It may be necessary to modify these temperatures for decreased atmospheric pressure.

† *Handbook of Food Preparation*, Report of the Terminology Committee of the Food and Nutrition Division of the American Home Economics Association, revised, 1950, by permission of the American Home Economics Association.

[64] Peet and Lowe, *Iowa Agr. Expt. Sta. Research Bull.* 213 (1937).

Not only oven temperature and size and shape of pan but also the kind of material from which the pan is made affect the cooking time and palatability qualities of such products as cakes. Shortened cakes in dull or dark pans such as those made from steel, japanned iron, anodized aluminum, and sheet iron bake faster than those in bright aluminum, tinned iron, stainless steel, or glass. In general, the faster-baking pans give products with larger volumes and better crumb quality but slightly inferior appearance so far as shape of the top is concerned. The slower-cooking metal pans also give preferable amount and evenness of browning. Cakes baked in glass tend to have thick crusts.[55] In baking angel food cakes, quick-heating pans such as enamelled or black iron types may produce toughness.[56]

Baking at High Altitudes

The decrease in atmospheric pressure at altitudes above 3000 feet is sufficient to cause problems in food preparation. The lowered boiling point of water retards cooking changes which proceed more rapidly at high temperatures and may not permit some of them to develop adequately even with longer cooking. Pressure cooking is a convenient method of shortening the preparation period for long-cooking vegetables and meats, and for canning. But in baking flour mixtures, additional problems related to the coagulation of egg and gluten and to the expansion of leavening gases are encountered. At very high altitudes (10,000 feet) water boils at 193 degrees F. (89 degrees C.). The rigidity developed in the egg and gluten gels is less. This effect can be balanced by reducing the proportion of the shortening and sugar and increasing the proportion of egg in cake recipes. Superglycerinated shortenings make it unnecessary to reduce the sugar as much as when other types are used.

The leavening gases expand more at high altitudes and, if supplied in proportions suitable for sea level, give coarse, crumbly textures and possibly fallen products. Reducing the amount of baking powder and, in angel food cakes, the amount of air beaten into egg whites compensates for the increase in expansion of carbon dioxide in the one case and air in the other. The tendency for more water vapor to form may require the addition of somewhat larger

[55] Charley, *Food Res.*, 15: 155 (1950).

[56] Reed et al., *op. cit.*

proportions of liquid to prevent dryness in some products.[57] The Colorado Agricultural Experiment Station has developed recipes adapted to high altitudes.

THE STORAGE OF FLOUR MIXTURES

All baked flour mixtures which have an elastic, spongy crumb deteriorate in eating quality after baking. The time required for change is generally shortest for those containing the highest moisture content. Muffins, waffles, griddle cakes, and popovers lose their fresh qualities so fast that they have no commercial importance. Cookies and crackers in moisture-proof packages retain high palatability the longest. Yeast-leavened products and cake have an intermediate rate of deterioration and offer the greatest problem. This is true of both household-baked and commercial products because bread and cake are consumed in greater quantities than other baked goods.

A loaf of fresh bread has been defined as one which has not stood longer after baking than required to reach room temperature or slightly above, a state that usually occurs in about 2 hours.[58] Such a loaf is not a stable product. On further standing, changes known as staling develop, although they may not be recognized by the consumer for several hours. These changes represent such a loss of palatability that commercial bread is seldom held on the market more than 3 days and may be considered fresh for 1 day only. From the standpoint of commercial bread production, staling represents such a cause of loss that a better understanding of its causes and methods of prevention than we have at present would be of great economic value.

Staleness is recognized by loss of fresh flavor and crispness of the crust, and such mouth-feel properties of the crumb as dryness, hardness, and inelasticity. The loss of crispness of the crust seems to be caused by absorption of moisture from the atmosphere or from the crumb. The alterations in the crumb are believed to be caused by two types of changes: loss of water from the loaf by evaporation, and colloidal transformation within the loaf. Although the total water-binding power of the bread colloids tends to diminish with age, it would be possible to prevent water loss from the loaf, to a

[57] Kulas, *J. Am. Dietet. Assoc.*, 26: 510 (1950).

[58] Platt, *Cereal Chem.*, 7: 1 (1930).

considerable degree at least, by using the proper type of wrapper, the proper amount of humidity in the storage atmosphere, etc. The prevention of loss of water from the loaf, however, does not prevent staling.

The colloidal transformations within the loaf which cause staling are still not entirely understood. In the past, the favored theory attributed the deterioration to changes in both the starch and the protein, postulating decreased hydrophilic quality of the starch and increased hydrophilic quality of the gluten which resulted in an exchange of water between them as the bread cooled and stood. More recently, evidence has accumulated to indicate that starch alone, and the amylopectin fraction in particular, is primarily responsible.[59]

Aggregation of the linear side chains of the branched molecules of amylopectin by some form of intermolecular association or hydrogen bonding is the explanation given. This type of retrogradation is much less firm than that involved in the retrogradation of the amylose fraction previously described and is reversible by heat. Every homemaker knows of the freshening effect of heating on stale rolls and bread, which agrees with this theory. In fact, in one test it was found that favorable results followed as many as seven reheatings of the same bread, after which water losses prevented reversion.[60]

Measures which delay staling of the crust may accelerate staling of the crumb and vice versa. In very humid air, the crust may become soft and leathery (stale) from absorption of moisture from the exterior, but, when it is wrapped in moisture-proof paper, it quickly develops this condition as a result of absorption of moisture from the interior of the loaf. Such wrapping is necessary for sanitary reasons and to retard the staling of the crumb caused by loss of moisture from the loaf; thorough cooling before wrapping is beneficial. Crust staling can be greatly retarded by storage of the unwrapped loaf in a moderately dry place, but this accelerates drying out and staling of the crumb. The same is true also of adjustments in ingredients or baking technics. Those which have a beneficial effect on the keeping quality of the crust tend to have a detrimental effect on the crumb.[61]

[59] Geddes and Bice, "The role of starch in bread staling," *Quartermaster Food and Container Institute*, QMC 17-10, Washington, 1946.

[60] Bailey, *Cereal Chem.*, 9: 65 (1932).

[61] Cathcart, *Cereal Chem.*, 17: 100 (1940).

Storage temperature has been found to be an important factor in the rate of staling of the crumb so far as the process is influenced by the colloidal changes. Several investigators agree that holding bread at a temperature of 140 degrees F. (60 degrees C.) or higher will maintain crumb softness for a long time, but bacterial and molc development at these temperatures produce "off" odors and flavor and, in a relatively short time, complete spoilage. Low-temperature refrigeration at 14 degrees F. (10 degrees C.), or less, also greatl retards staling. Thus fresh bread placed in a deep freezer largely re tains its freshness for long periods. Certain ingredients, including milk, potato, shortening, gelatinized starch (as in scalded flour), soybean flour, and rye flour, are said to have a favorable effect on staling as judged by eating quality, if not on physical measures of change in the crumb.

The demand of consumers for freshness in purchasing bread and their use of the "squeeze" test to measure it are factors which have led to the production of commercial bread which is characterized by extreme softness and sponginess. Commercial bakers emphasize processes and ingredients that give these qualities to a degree that leads to the criticism that their bread lacks substance and flavor when compared with the homemade product. Chemical bread softeners have been found which are more effective than shortening in producing these qualities. Establishment of a definition for bread by the federal Food and Drug Administration was delayed by the controversy between the industry representatives and more consumer-minded groups over giving official approval of the use of such bread softeners. Competition among bread distributors which leads to the practice of removing unsold bread daily and selling it at a low price as stale bread or animal feed increases the cost of all bread. Consumers who toast most of their bread need not be concerned about extreme freshness. Those who eat substantial quantities without toasting might refreshen it by heating just before eating. The industry could also help by providing small loaves for small families so that bread might be purchased daily.

Low temperature baking, applied primarily to rolls, gives the consumer the advantages of freshness with little additional labor. The products, known as "Brown 'n Serve" bread and rolls, are almost completely baked but lack crust color because the baking temperatures employed are too low to cause browning. A few minutes of heating at 400 to 425 degrees F. (204 to 218 degrees C.) produces the desired browning together with the fresh qualities

of taste and texture that we prefer. Products of this type may be made at home and stored at room temperature for as long as 1 week, in a refrigerator for 2 weeks, or in a freezer for as long as 3 months before the final baking.*

Freezing Flour Mixtures

The period of holding many flour mixtures both before and after baking may be greatly prolonged if they are frozen. Yeast products may be frozen in the dough stage, after mixing and before fermentation, but their volume and grain when baked are inferior. Undesirable compact layers often develop in the dough after as little as 1 day of frozen storage. In one case, after 8 weeks of frozen storage the products were considered unsatisfactory,[62] but in another set of experiments it was found that unbaked products could be held in frozen storage up to 3 months.[63] In general, freezing *after* baking permits longer holding and is recommended for yeast-leavened products.[64]

Biscuits, cookies, cakes, and pies compare more favorably with the freshly baked counterpart if they are frozen in the uncooked form rather than after baking.[65] However, freshly baked goods of these types *may* be frozen with reasonably satisfactory results. It has been found that, in the case of cakes at least, those prepared from frozen batter, and reheated frozen cakes, retain their freshness as well as those which have not been frozen at any stage.[66]

Cakes made from recipes which are proportioned for high altitudes also give acceptable products after freezing in either the batter or baked stage, if double-acting baking powder and superglycerinated vegetable shortenings are used.[67] The latter types of ingredients are apparently preferable at all altitudes.[68]

It is particularly important in products which are to be frozen that all ingredients be of high quality. Genuine vanilla should be

* Recipes and directions can be obtained from the Agricultural Extension Service in your state.

62 Zaehringer et al., *Food Res.*, 16: 353 (1951).

63 Meyer et al., *Univ. of Tenn. Agr. Expt. Sta. Bull.* 223 (1951).

64 Beattie et al., *Food Technol.*, 3: 160 (1949).

65 Sunderlin, *Quick Frozen Foods* 7, No. 8, p. 88 (1945). Miller and Beattie, *J. Home Econ.*, 41: 463 (1949). Owen and Van Duyne, *Food Res.*, 15: 169 (1950).

66 Owen and Van Duyne, *ibid.*

67 Zaehringer and Mayfield, *Food Technol.*, 5: 151 (1951).

68 Mackey et al., *Food Res.*, 17: 216 (1952).

used rather than the synthetic product. Spices should usually be omitted from goods which are to be held in frozen storage more than a few weeks. As little as 5 per cent of soy flour in pastry mixes made with lard retards the development of rancidity in pie crust whether it is baked before or after freezing.[69]

THE APPRAISAL OF FLOUR MIXTURES

Among the flour mixtures eaten by the average person in this country none appears more often than bread. Federal definitions for bread, enriched bread, milk bread, raisin bread, whole-wheat bread, and rolls have been established. These standards largely conform to the previous practices of the industry except that softeners of the polyoxyethylene monostearate group are prohibited, and breads labeled "whole wheat," "graham," or "entire wheat" must contain only whole-grain flour. The flours used in bread may be bromated or phosphated, and optional ingredients include shortening (with or without lecithin and limited proportions of mono- and diglycerides), limited amounts of milk and milk products, egg, certain specified sugars or sirups, malt products, yeast, lactic acid bacteria, limited amounts of a variety of other flours and starches, limited amounts of certain calcium, potassium, and phosphate compounds, and vinegar. The definitions do not exclude the use of other wholesome ingredients or larger proportions of many of those listed above, but these must be indicated on the label. If the bread is enriched, the specified amounts of the added nutrients per pound of bread are: 1.1 to 1.8 milligrams of thiamine, 0.7 to 1.6 milligrams of riboflavin, 10.0 to 15.0 milligrams of niacin or niacinamide, and 8.0 to 2.5 milligrams of iron. Optional ingredients include 150 to 750 USP units of vitamin D and 300 to 800 milligrams of calcium per pound of finished bread.

Nutritive Quality of Flour Mixtures

According to a survey of the BHNHE, the per capita weekly consumption by urban families averaged about 1½ pounds per week of bakers' bread, or almost ¼ pound per person per day, with some families consuming as much as 3 pounds per person per week. This

[69] Overman, *Food Res.*, 12: 365 (1947).

equaled about one-half of the total flour eaten in all forms and provided such a substantial proportion of the average person's daily requirement for some nutrients that the balance of other nutrients in the bread is exceptionally important.

In general, the relative nutritive balance of bread depends upon the kind of flour used, whether it is plain white, enriched, or whole grain, and how much milk solids it contains. (See Table LXII.) The use of whole wheat is limited because a 100 per cent whole-wheat bread has a compact texture and coarse grain which are entirely unacceptable to most people. Prior to the issuing of standards of identity for whole-wheat bread, much of the so-called "whole wheat," "graham," and "entire wheat" bread on the market contained only 50 per cent or less of whole-grain flour.

In the 26 states, Hawaii, and Puerto Rico, which had passed compulsory enrichment legislation by 1951, commercial white bread and plain rolls were usually the finished products covered. Those containing mixtures of white flour and cracked wheat, whole wheat, rye, etc., and sweet rolls were not included. The reasons for limiting coverage in this way are (1) white bread and plain rolls constitute by far the largest proportion eaten, and (2) enforcement is greatly simplified. In spite of the limit on the number of products required to be enriched, it was estimated in 1951 that two-thirds of all the white flour milled in this country reached the consumer enriched at the mill or in the bakery.

As stated in the section on flours, the enrichment of flour and bread is generally approved and advocated by nutritionists and the medical profession. However, enrichment does not make white bread the complete equivalent of 100 per cent whole-wheat bread and is not intended to do so. Consumption of some whole-wheat bread is still desirable because the natural grain may contain unknown nutrients of value and because the roughage it contains may be beneficial. The inferiority of the proteins of the endosperm to those of the whole grain is reduced by the widespread practice of adding milk solids to white bread. Proportions up to 6 per cent of the weight of the flour are commonly used by commercial bakers. Besides adding substantially to the quantity and quality of protein, milk products augment the calcium and riboflavin in bread. Preference tests show not only that bread made with dry skim milk is preferred to that made with water, but that increasing the level of the milk solids to as much as 14 per cent of the weight of the flour

Table LXII. The nutritive contributions of bread, given as percentages of the *Recommended Allowances* for a physically active man

[Babcock, *N. J. Agr. Expt. Sta. Bull.* 751 (1950)]

Food, measure and description	Food nutrients								
	Energy	Protein	Calcium	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Ascorbic acid
White bread, unenriched, 2% nonfat milk solids, 100 grams (about 4 slices)	9	11½	6½	5	0	3½	4½	6	0
White bread, unenriched, 6% nonfat milk solids, 100 grams (about 4 slices)	9	12½	9	5	0	3½	6½	6	0
White bread, enriched, 2% nonfat milk solids, 100 grams (about 4 slices)	9	11½	6½	15	0	16	8½	14½	0
White bread, enriched, 6% nonfat milk solids, 100 grams (about 4 slices)	9	12½	9	15	0	16	8½	14½	0
Whole-wheat bread, 100 grams (about 4 slices)	8	13½	9½	18½	0	20	7	20	0
Fifty per cent whole-wheat bread, 100 grams (about 4 slices *)	8½	12½	8	11½	0	12	6	13	0
Cracked-wheat bread, unenriched flour, 100 grams (about 4 slices)	8½	12	8½	8½	0	7½	5½	9½	0
Rye bread, American, ⅓ rye, ⅔ clear flour, 100 grams (about 4 slices)	8	13	7	13½	0	12	4½	10	0

* Values estimated from data on whole-wheat and unenriched white breads.

leads to progressive increase in consumption of the bread under test situations.[70]

Analyses of the calcium content of commercial bread show a very wide range in the amount of milk solids used. The high consumer (3 pounds per week) might obtain from as little as 2 per cent of the *Recommended Allowance* of calcium to as much as 32 per cent. It would thus be useful to have some indication of this difference on the label.[71]

Other natural food supplements which increase the nutritive value of bread, particularly its protein and vitamin value, are wheat germ and soy flour. Cornell University scientists have developed a formula which includes enriched flour, wheat germ, nonfat dry milk, and high-fat soy flour, a formula which is markedly superior in nutritional value, especially protein, to ordinary enriched bread. Its palatability makes it attractive to consumers in areas where it is available. Addition of these ingredients increases the cost by only about 1 cent per pound of bread.*

Building up the nutritive value of bread in these ways is a highly desirable method of improving the nutrition of families in low-income groups, of persons in institutions, and of school children who eat in school lunchrooms—groups whose bread consumption is relatively high. Though increases in cost are small, possible reduction in loaf volume and an off-white color make commercial bakers slow to adopt formulas enriched by wheat germ and soy flour. Furthermore, the Food and Drug Administration has refused to broaden the definition of white bread to include these ingredients. Such bread is required to bear a descriptive or special name.

Nutritive losses in the baking of yeast-leavened products are limited to thiamine. Not more than one-fifth of the original amount in the dough is ordinarily inactivated and this is largely in the crust. The more crust and the browner the stage to which it is baked, the larger the loss. Time and temperature of heating are important factors; at a given temperature of baking, the longer the time of heating, the greater is the loss. Rolls undergo smaller losses than bread, presumably because the time for baking is less and the crust is thinner. These factors more than outweigh the increase in

[70] Jack and Haynes, *Food Res.*, 16: 57 (1951).

[71] Goddard and Marshall, *U. S. Dept. Agr., Tech. Bull.* 1055 (1952).

* Recipes for the Cornell bread can probably be obtained from your State Agricultural Extension Service.

proportion of crust.[71a] In commercial enriched bread and rolls, baking losses of thiamine are offset by addition of an extra amount because enrichment standards apply to the finished product.

Toasting also reduces the thiamine value of bread. In medium toast, the loss may amount to as much as one-eighth; it is greater in melba toast.[72]

Baked goods should not be exposed for long periods (several days) to direct sunlight because this results in marked losses of riboflavin. Waxed paper wrappings are much more effective than cellophane in reducing the inactivation.[73]

So far as the nutritive value of other flour mixtures is concerned, those high in plain white flour and fat or sugar, and low in milk and eggs, are unbalanced in their contributions. (See Table LXIII.) Thus muffins and sponge cakes are better sources of protein, minerals, and vitamins in relation to their calorie value than pastry and plain cake. In fact, flour products high in fat or sugar or both, are so unbalanced nutritionally that persons with relatively high requirements for nutrients other than calories, such as growing children or adults with low or moderate energy expenditures, should restrict consumption of these foods below the levels often stimulated by their appetite appeal. Fresh or frozen fruits or those canned in a light sirup, or bits of a tasty cheese, are desserts that supplement rather than unbalance the usual diet. It is not necessary for most persons to eliminate pies, cakes, doughnuts, etc., entirely, provided the remainder of the food in the diet is intelligently chosen to include recommended amounts of milk and nutritionally efficient fruits and vegetables (those high in vitamin A value and in ascorbic acid). But the habit of eating these flour mixtures in only small servings is necessary for most adults if they are to maintain nutritional balance and avoid overweight.

The adoption of enriched flour for all or almost all household baking is desirable, but attention should be paid to the balance of chemical leavening called for in recipes, because many of the older ones specify excessive proportions of soda. Neutralization of all soda should be attempted. If there is an excess after the neutralizing action of sour milk, molasses, or cream of tartar is accounted for, an extra amount of acid (cream of tartar) should be added. Other-

[71a] Zaehringer and Personius, *Cereal Chem.*, 26: 384 (1949).

[72] Downs and Meckel, *Cereal Chem.*, 20: 352 (1943). Hoffman et al., *Cereal Chem.*, 17: 737 (1940).

[73] Loy et al., *Food Res.*, 16: 360 (1951).

Table LXIII. The nutritive contributions of typical flour mixtures, given as percentages of the *Recommended Allowances* for a physically active man

[Babcock, *N. J. Agr. Expt. Sta. Bull.* 751 (1950)]

Flour mixtures, description and measure	Energy	Protein	Calcium	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Ascorbic acid
	Food nutrients								
Biscuits, baking powder (1 biscuit, 2½ in. diam., 38 gms.)									
unenriched flour	4½	4½	8½	1½	0	1½	1½	1½	(0) *
enriched flour	4½	4½	8½	6	0	6	4½	4½	(0)
Cake									
angel food (2-in. sector, 1/12 of 8-in. diam., 40 gms.)	3½	5	0	1	0	0	3	½	(0)
fruit, dark (1 piece, 2 x 2 x 2½ in., 30 gms.)	3½	2½	3	6½	1 [a]	2½	2	2	(0)
plain (1 square, 3 x 3 x 1½, 55 gms.)	6	5	8½	1½	1½ [b]	1½	3	1½	(0)
rich with plain icing (2-in. sector of layer, 1/16 of 10-in. diam., 130 gms.)	16½	8	11½	5	4½ [c]	2	5½	1½	(0)
sponge (2-in. sector, 1/12 of 8-in. diam., 40 gms.)	4	4½	1	5	4	1½	3½	½	(0)
Cookies									
plain and assorted (1 cooky, 3-in. diam., ½ in. thick, 25 gms.)	3½	2	½	1½	(0)	½	½	½	(0)

Doughnuts (1 doughnut, 32 gms.)	4½	3	2½	1½	1	3½	2	2½	(0)
Gingerbread (1 piece, 2 x 2 x 2 in., 55 gms.)	6	3	6½	11½	1	1½	3	4	(0)
Muffins (1 muffin, 2¾-in. diam., 48 gms.)									
unenriched flour	4½	5½	10	2½	1	1½	3½	1½	(0)
enriched flour	4½	5½	10	6½	1	6	5½	4½	(0)
Pancakes, wheat (1 cake, 4-in. diam., 27 gms.)									
unenriched flour	2	2½	4½	1½	1	1½	1½	½	(0)
enriched flour	2	2½	4½	3½	1	3½	3½	2	(0)
Pie									
apple (4-in. sector, 1/7 of 9-in. diam., 135 gms.)	11	4	1	4	4½	2½	1	2	1½
cherry (4-in. sector, 1/7 of 9-in. diam., 135 gms.)	11½	4½	1½	4	10½	2½	1	2	2½
custard (4-in. sector, 1/7 of 9-in. diam., 130 gms.)	9	9½	16	13½	6	4½	11½	2½	(0)
mince (4-in. sector, 1/7 of 9-in. diam., 135 gms.)	11½	5	2	25	0	6	3	3½	1½
pumpkin (4-in. sector, 1/7 of 9-in. diam., 130 gms.)	9	8	7	8½	49½	2½	8½	2½	(0)
Waffles (1 waffle, 4½ x 5⅝ x ½ in., 75 gms.)									
unenriched flour	7	10	14½	6½	5½	3½	8	2	(0)
enriched flour	7	10	14½	11½	5½	9½	11	6½	(0)

* Imputed values are in parentheses.

Note: If the fat used in the recipe is butter or fortified margarine, the vitamin A value would be increased to the following: [a] 2½ per cent; [b] 4 per cent; [c] 18 per cent.

wise the surplus soda should be omitted and substituted for by the appropriate amount of baking powder. Theoretically, the amount of baking powder substituted should contain about half as much soda as the excess because the latter would have yielded only about one-half of its carbon dioxide when heated in the absence of sufficient acid to neutralize it.* Such adjustment will not give a product identical with that of the original recipe. Excess soda itself produces certain effects on taste and color, and possibly also on texture because alkalinity makes gluten more tender. The change in taste at least will be approved by anyone who has not been conditioned to alkalinity by long experience.

Although there is some inactivation of thiamine and possibly of niacin in products containing baking powder, this need not amount to more than a fourth of the total as indicated by studies of doughnuts and other products.[74] In baking powder biscuits, for example, it has been found that the proportion of the original thiamine retained after baking is related to the *p*H of the biscuits. When phosphate baking powders were used, retention was about 85 per cent at *p*H of 7.1 or lower. In one series in which the *p*H was adjusted by adding soda, over half of the thiamine was lost when the alkalinity reached *p*H 7.3. The composition of the acid salt in the baking powder as well as its effect on the hydrogen-ion concentration of the product is a factor in thiamine inactivation, probably on account of differences in response to heat and hence in the *p*H of the dough during baking.[75] A *p*H of 7.0 (neutrality) gives comparatively high retention, and, because increasing acidity results in low volume and hence less attractive texture, this appears to be the desirable reaction.[76] Losses of thiamine in both biscuits and cake need not, as a matter of fact, be any greater than that in bread.[77]

The nutritional balance of flour mixtures other than bread, as well as that of bread itself, may be improved by using enriched or whole-grain flours and by including wheat germ, soy flour, and extra amounts of milk in dry, skim, or undiluted evaporated forms. Even

* One teaspoon of *unneutralized* soda yields carbon dioxide equal to ½ teaspoon of neutralized soda. This in turn is equal in leavening power to 2 teaspoons of baking powder.

[74] Everson and Smith, *Science*, 101: 338 (1945).

[75] Barackman, *Cereal Chem.*, 19: 121 (1942). Williams and Fieger, *Food Res.*, 9: 328 (1944). Briant and Hutchins, *Cereal Chem.*, 25: 512 (1946).

[76] Arny and Hanning, *J. Am. Dietet. Assoc.*, 23: 690 (1947).

[77] Melnick et al., *Cereal Chem.*, 20: 661 (1943).

pies become relatively well-balanced foods when they are made with one crust and have fillings of plain, pumpkin, or cheese custard.

Digestibility of Flour Mixtures

The completeness with which bread and other flour mixtures are digested is controlled largely by the degree of milling to which the flour has been subjected. Whole-wheat breads have a greater indigestible residue which adds to their value for roughage, but, like the action of whole grains in other forms, may be too harsh and irritating to the intestines of a small proportion of individuals. The extra roughage does not interfere with the completeness of digestion of the fat or carbohydrate, which is approximately the same for white and whole-wheat bread, but is associated with somewhat less complete absorption of the protein.[78] Toasting dextrinizes a portion of the starch, but, as in the case of prepared breakfast foods, the principal advantage to be attributed to this change is the favorable effect on flavor.

There is no evidence that ingredients in flour mixtures change in digestibility properties, either as to time in the stomach or completeness of absorption. Those high in fat leave the stomach in from 2½ to 3 hours. Doughnuts in particular have been found to be as completely digested as the same ingredients in other forms. The popular notion of relative "indigestibility" of rich desserts is probably derived from the occasional discomfort caused by adding them to an already sufficient meal. The satiety value of these products makes them particularly appreciated by persons engaged in vigorous physical activity, and, of course, such persons are less likely to unbalance the nutritive value of their day's meals by including them.

Sanitary Quality of Flour Mixtures

The sanitary quality of bread and other baked products depends largely upon the handling of them after baking. Both the processes of milling and of commercial baking are usually supervised to ensure cleanliness.

The temperatures of baking are sufficient to minimize danger from accidental contamination of flour mixtures with pathogenic organ-

[78] Sealock et al., *J. Nutrition*, 22: 589 (1941). Murlin et al., *J. Nutrition*, 22: 573 (1941).

isms. Commercial bakeries which wrap breads and other products ensure their arrival to the consumer with the least contamination in the interval after baking. Intelligent bakers desire sanitary handling of their goods to prevent infection with common spoilage organisms such as molds and bacteria.

Custard-type fillings in pies, layer cakes, cream puffs, etc., are the greatest potential food-poisoning hazards among all flour products because they are suitable media for the development of *Staphylococci.* Careless handling of the custard and failure to clean equipment with which it comes in contact is the usual cause. These products should always be refrigerated if held after baking.[79] They have frequently been the cause of this type of food poisoning.

The search for ingredients which would retard staling of flour mixtures has led to the use of a number of chemicals in commercial baking, particularly in the baking of bread and cake. Those of the polyoxyethylene monostearate group, which have been widely employed for their softening action, have been questioned as to possible deleterious properties. In setting up its standard for bread, the Food and Drug Administration has refused to include softeners from this group as optional ingredients until more complete proof of their harmlessness is obtained. Their use in other flour mixtures which have not been officially defined has not been prohibited, however.

Palatability of Flour Mixtures

The standards for high eating quality in the individual types of baked flour mixtures will be given in Part F. In general, the bland flavor of bread makes it a more acceptable part of meals and between-meal snacks than any other food unless it is the butter or margarine commonly served with it. The tendency for commercial bakers is to emphasize large volume, softness, and elasticity in bread because consumers judge values by the eye (rather than reading labels for weight) and because they use the "squeeze" test for freshness. (See the discussion of staling.) For many consumers, this trend has led to a loaf that has less appetite appeal than that of the more compact loaf ordinarily prepared in the household.

Nevertheless, the most frequent complaint of consumers about commercial bread is that it lacks keeping quality.[80] Probably the

[79] Abrahamson et al., *Food Res.*, 17: 268 (1952).

[80] Adelson, *J. Home Econ.*, 38: 627 (1946).

tendency to mold is what is meant when this criticism is made, rather than staling in the technical sense. Under conditions where mold development is a problem, buying bread in the smallest sizes of loaves available and storing it in a refrigerator in the original wrapper will retard the growth. If the true staling which develops at this temperature is objectionable, it can be remedied by a brief reheating just before eating.

The endless possibilities of combining the appetite appeals of sweetness, the richness in flavor contributed by fat, and the browning and other changes in the crust, together with a variety of texture and eye appeals, give flour mixtures other than bread their great popularity. Skill in preparing flour mixtures creates more prestige for the cook than that exhibited in the preparation of any other group of foods. In consideration of their nutritional shortcomings, this is unfortunate. Except for bread and rolls, the preparation of which has so largely left the household, skill in cooking vegetables and less expensive cuts of meat, and in preparing cheese, milk, and egg dishes, to increase their appetite appeal would contribute more to the health of the population.

As pointed out in the case of bread, most commercially prepared flour products of other sorts do not equal their household counterparts in readily attained standards of eating quality. This is probably a result in part of the effects of production in large quantity, and in part of staling and other problems of distribution. Also, eye appeal has more selling power than other qualities less discernible at the market, and the attention of bakers is centered on enhancing it. Then, by the use of transparent wrappings and strategic location in the store, "impulse buying" is stimulated, reducing the incentive of the industry to improve texture and flavor properties.

Economy of Flour Mixtures

Bread is one of the cheapest foods we eat. Consuming it in larger than average amounts is the simplest way of keeping food costs down. This can be done and a high standard of nutritive adequacy in the whole diet maintained by making the bread itself more nutritious and by building menus which balance the nutritive deficiencies of bread efficiently. Milk (or skim milk) and fruits and vegetables chosen for their vitamin A and vitamin C value are most important.

When stale (day-old) bread is sold at a discount, it is a good buy, if it can be eaten before it is spoiled by mold. Reading labels to select enriched or whole-grain products and to compare values in terms of quality helps the buyer to get the most for her money.

Baking bread and rolls in the household is advantageous for families trying to budget expenditures for food most efficiently. Ingredients and fuel do not cost as much as the finished commercial products; hence there is some return for labor which may otherwise have no money value. Household products can be made more nutritious than those usually available on the market by incorporating extra amounts of dry skim milk and by including wheat germ and soy flour. Finally, almost anyone *can* acquire the knowledge and skill to bake bread and rolls superior in palatability to market products, at least when they are freshly baked. The increased consumption which results saves money, because most foods for which these are substituted cost more. To the extent that bread or rolls are substituted for products high in sugar, a nutritional gain is also achieved.

So far as other flour mixtures are concerned, flour and sugar are among the cheapest raw materials entering into our diet. The cost of the milk can be greatly reduced by using nonfat milk solids. In commercial production, the cost of eggs is minimized by using the dried and frozen forms. In general, next to bread, flour mixtures of many other types than bread are among the less expensive sources of energy and to a lesser degree of other nutrients (except vitamin C). When comparable ingredients are used, household baking of flour mixtures other than bread gives a substantial return for the labor involved in making them.

DRY FLOUR MIXES

An increasing number of kinds of flour mixtures have become available on the market in premixed dry forms in packages of household size. They may contain all ingredients except water, or in some cases require the addition of milk or eggs or both. The creation of shortenings which are resistant to rancidity has been an important factor in their development because the resultant increase in "shelf-life" is essential to make marketing in this form practicable. The rapid expansion in sales of commercial mixes has been one of the most spectacular developments in postwar retailing.

Much of the time-saving advantage of using commercial mixes can be obtained by preparing quantity mixes at home. It requires little more time, for example, to measure and combine the dry ingredients for ten pies than for one. In a study of corn muffin mixes, it was found that the outstanding advantage was the saving of time and effort, and the muffins were equal to or superior to those made from individually mixed batches.[81] Master mixes which can be supplemented with appropriate additional ingredients to prepare a variety of biscuits, muffins, cakes, and cookies have also been devised.[82]

The Appraisal of Dry Flour Mixes

Nutritive Quality of Dry Flour Mixes

When the same ingredients are used, it makes no difference in the nutritive value of the product made from them whether they are purchased separately or in commercial mixes, or combined and held as dry mixes in the household. The principal disadvantage in the purchase of commercial mixes is the lack of information given as to proportions of ingredients. The label simply lists "Nonfat dry milk," for example, without revealing how much of this nutritionally important food is present. Furthermore, except in bread and roll mixes, enriched flour is seldom used. Enrichment costs so little that no doubt any evidence of demand for it in other kinds of mixes would be met by manufacturers without any increase in prices. In any case, there is no basis for differentiating between commercial mixes and ready-to-eat baked goods so far as nutritional value is concerned.

Digestibility of Dry Flour Mixes

There is at present no reason to expect that the digestibility of products made from commercial mixes differs from that of similar products made up at home.

Sanitary Quality of Dry Flour Mixes

The sanitary quality of either commercial or homemade mixes does not appear to present any particular problem. Their low moisture

[81] Gothard, *J. Home Econ.*, 43: 713 (1951).

[82] Sunderlin, *A Master Mix and More than 60 Variations*, Purdue University, 1948.

content retards development of bacteria which might be present, and subsequent baking probably kills pathogenic organisms in any event.

Palatability of Dry Flour Mixes

So far as palatability is concerned, the primary aim of manufacturers of commercial mixes is "fool-proofness," that is, the certainty that the mix will yield a reasonably acceptable product in the hands of a cook who is inexperienced and unlikely to read and follow more than very limited instructions on a label. Probably the most frequent cause of failures in the household preparation of flour mixtures is faulty measurement or lack of uniformity in the kinds of ingredients, particularly the flour. Commercial mixes can be uniform in both proportions and kinds of ingredients. Furthermore, the manufacturer of mixes can often obtain specialized ingredients, such as shortening, not available on the retail market.

In general, it is probably fair to conclude that the use of commercial flour mixes makes it possible for the homemaker who is inexperienced or in a hurry to prepare products which are at least reasonably acceptable for everyday use. Furthermore, she can be fairly certain what their eating quality will be as compared with those made previously from the same mix. Careless or unskilled cooks may obtain both greater uniformity and acceptability with commercial mixes than with separate ingredients. On the other hand, trained and experienced cooks can attain both greater individuality and superior palatability in products made according to well-balanced recipes, whether these are freshly combined or fractions of a previously combined dry mix.

Economy of Dry Flour Mixes

Perhaps the greatest appeal of commercial flour mixes to the homemaker is the saving in time and labor resulting from their use as compared with assembling and measuring individual ingredients. In addition, rarely used ingredients need not be stocked, a saving both of shelf space and of waste from deterioration. As fewer utensils are required, dish washing is reduced.

Published studies of comparative costs of ingredients in mixes and similar household recipes are limited in the number of such reports and in the products covered. In one such investigation, pie crust made with lard costing 10 cents and that made with hydrogenated shortening costing 13 cents compared with a commercial mix priced

at 17 cents. Devil's food cakes made from household ingredients cost 50 cents, whereas those made from two commercial mixes cost 41 cents and 38 cents each. The cooks, who were students in a college class in foods, considered their individually measured products superior in palatability to those made from the commercial mixes.[83]

Exact cost comparisons are not possible because proportions in the commercial mixes are not revealed, but the following procedure is suggested:

1. Estimate dry weight of the household recipe.

Ingredient by volume	Weight
Sugar, 1 cup	7.25 ounces
Flour	
all-purpose, 1 cup	4.0 ounces
pastry and cake, 1 cup	3.5 ounces
Corn meal, 1 cup	5.5 ounces
Vegetable shortening, 1 cup	7.25 ounces
Lard or oil, 1 cup	8.0 ounces
Dry skim milk, to equal 1 cup fluid milk	1.0 ounces
Dry whole egg, to equal 1 fresh egg	0.5 ounces
Baking powder, 2 tablespoons	1.0 ounces
Cocoa, 1 cup	4.0 ounces

2. Estimate cost of a household recipe. Where whole milk is called for, use cost of dry skim milk (because this is used in all commercial mixes) but include cost of an extra tablespoon of shortening for each cup of skim milk so substituted.
3. Estimate cost per pound or ounce of household recipe as a dry mix.
4. Compare with cost per pound or ounce of commercial mix.

A trend toward narrowing the margins between mixes and individual ingredients as a result of competition will probably continue to reduce price differences, but thus far commercial mixes average substantially more in cost than similar ingredients measured at home. It should be remembered that a few cents' increase may be a considerable percentage of the price of such products, and, if applied to the proportion of the food expenditures concerned, this amounts to a surprising total over a month or year. As previously stated, much of the time-saving advantage of a commercial mix can be obtained by preparing a dry mix at home, thus saving the difference in cost of ingredients in the commercial mix.

[83] Morr, *J. Home Econ.*, 43: 14 (1951).

SUMMARY OF POINTS TO CONSIDER IN SELECTING AND USING FLOUR MIXTURES

1. To obtain best value for the price, bread should be bought according to information on the label about composition and weight of the loaf. Whole-grain or enriched types made with milk are preferable for regular use. Sweet rolls are generally more expensive than plain rolls and are not usually enriched.

2. Household baking of bread, on the scale of more than one or two loaves at a time, gives a fair return for the labor involved. If the homemaker is skillful enough to obtain a product of high quality so that it is eaten in larger amounts than the commercial product, another saving results from its substitution for more expensive foods. Fresh, home-baked rolls, in particular, may be a satisfactory substitute for sweet desserts to the nutritional advantage of all.

3. Commercial baked goods other than bread and rolls are generally rated as inferior in palatability to products made in the household by skilled cooks. This difference is in part a result of differences in ingredients and freshness, and probably also a result of the fact that the flavors of products mixed in factory quantities are not the equal of those prepared on a smaller scale. Comparative nutritive values are difficult to judge because the exact formulas of commercial products are not given on the labels. On a cost basis, it can be assumed that, on the average, home baking makes some return for labor. The principal advantage of a commercial product is the saving of labor, but, for the inexperienced cook, uniformity of palatability may also be the basis of purchase.

4. Frozen storage of flour mixtures in either the ready-for-baking or ready-to-eat stage offers the advantages of more efficient use of labor in preparing larger quantities at one time, and of convenience in having partially or completely prepared products on hand.

5. Commercial dry mixes offer the advantages of requiring less skill to produce products of uniform quality, less labor, and less waste and storage space than separate ingredients. On the other hand, they generally do not equal in palatability products made according to household recipes by skilled cooks. Their comparative nutritive values are impossible to judge. Their cost is usually substantially higher. Part of the labor-saving advantage of the commercial mix can be achieved by preparing basic mixes of dry ingredients in quantity at home.

PART F. *THE PREPARATION OF TYPICAL FLOUR MIXTURES*

Yeast bread and rolls	Muffins
Biscuits	Shortened cakes
Pastry	Unshortened cakes
Griddle cakes and waffles	Cookies
Popovers and cream puffs	Doughnuts

This section will be devoted to the preparation of the types of flour mixtures of greatest importance in the average household. The discussion of each type of product will cover palatability standards, kinds and proportions of ingredients, manipulating technics, and baking.

Yeast Bread and Rolls

The baking of a leavened dough by mixing wheat flour with water, sugar, salt, shortening, and yeast, and allowing it to ferment is one of the most important methods of producing a palatable food from this grain. The manufacture of yeast bread in the household has decreased as the manufacture of commercial bread has increased. The bakery products industry is second in total value of goods only to meat packing among all food industries in the United States. Modern flour mills and bakeries have become laboratories of applied chemistry, and commercial breadmaking has become one of the most scientifically conducted of processes. At the same time, baking bread in the household has become a more controllable operation with the result that the homemaker can expect to obtain products of a quality often preferred to those on the market with less effort and probability of failure than formerly. This advance is a result of greater uniformity of present-day flours, superiority of modern yeasts, improvement in oven control, and improved technics based on experimental studies of the various factors affecting quality of bread made under household conditions.

PALATABILITY STANDARDS

Qualities considered desirable in bread involve the general appearance of the loaf, the appearance and feel of the crumb when cut, and the flavor. Loaves should be large for their weight, indicating lightness. They should have a golden brown crust and rounded tops with no cracks or bulges. The crumb grain should be fine; the cells,

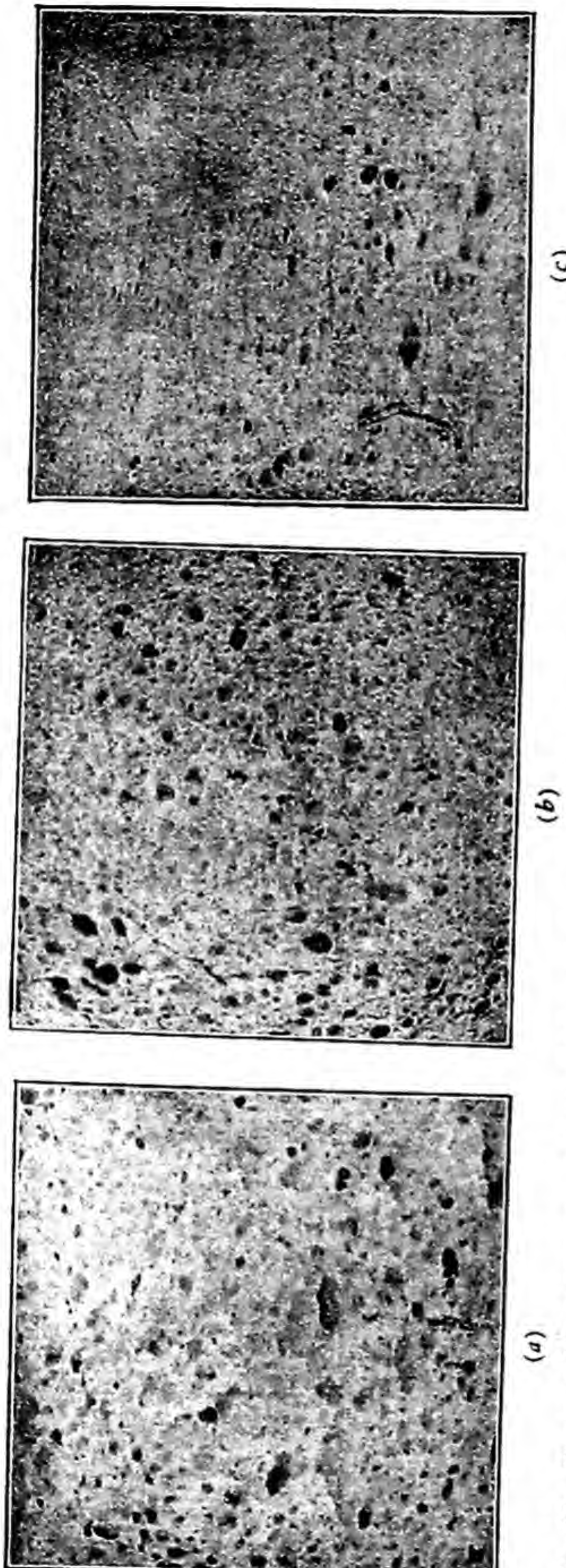

FIG. 44. Photographic appearance of loaves with varying grain. (*a*) Coarse grain; (*b*) medium grain; (*c*) fine grain. (*Courtesy of M. J. Blish.*)

small, thin-walled, uniform, and slightly elongated. (See Fig. 44.) In texture, bread should be smooth, soft, and elastic, qualities which are associated with thin cell walls. The color should be creamy-white, and the cut surfaces should have a silken sheen in the light. The flavor should be sweet and nutty.

Kinds and Proportions of Ingredients

On the basis of the weight of the flour as 100, a typical bread recipe contains about 65 per cent as much water or milk, 2 per cent yeast, 2 per cent salt, 6 per cent sugar, and 4 per cent shortening.

The Flour

In making yeast-leavened bread, strong flours are preferred because they make the largest, spongiest loaves under the widest variety of conditions. This capacity is largely dependent upon their high protein content. (See Table LXIV and Fig. 45.) But good

Table LXIV. Results of chemical and baking tests on flours from different wheats

[After Thomas]

Type of wheat	Hard red spring	Hard red winter	Soft red winter
Weight per bushel, lb.	60.5	62.1	61.4
Yield of flour, per cwt.	70.2	72.0	69.7
Loaf volume, cc.	2421	2219	1965
Water absorption, per cent	55.7	55.2	52.4
Crude protein (N times 5.7):			
In wheat, per cent	12.9	12.1	10.6
In flour, per cent	11.9	11.2	9.6

bread by household standards can be made from soft-wheat (weaker) flours by appropriate adjustment in proportions of other ingredients and manipulative technics.

The Yeast

Yeast, as previously explained, serves the function in a dough of producing the carbon dioxide from sugar which results in leavening. Dry dormant yeast must be activated by preliminary fermentation in a sponge, a mixture of part of the flour with the yeast and the liquid.

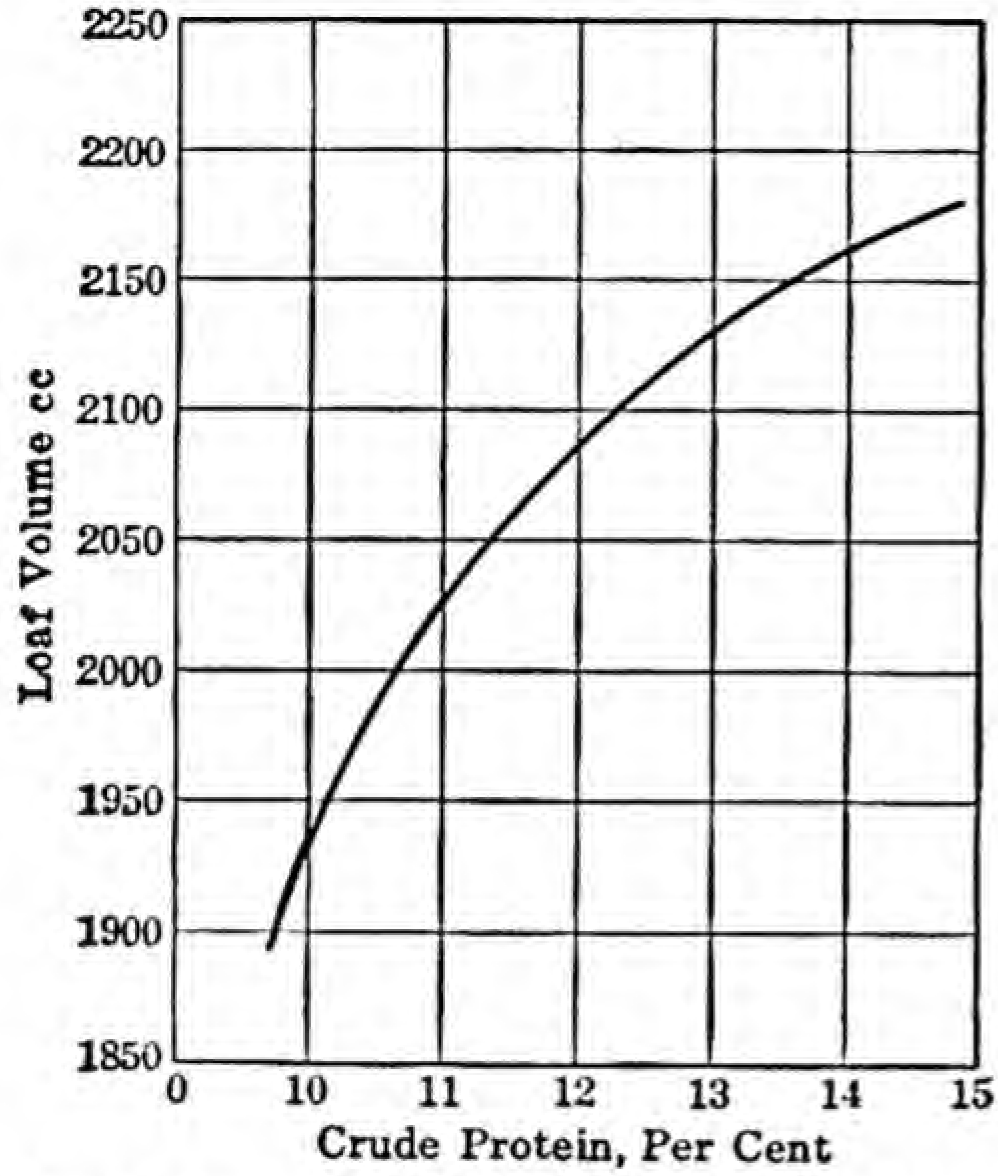

FIG. 45. Relation of loaf volume to crude protein content of hard spring wheat flour. (*Bailey and Sherwood.*)

In general, the rate of gas production is proportional to the amount of yeast added when other conditions are equal. But too much yeast results in reduced loaf volume and a yeasty odor in the product. Too little yeast produces slow fermentation. A relatively large proportion of yeast is desirable to accelerate fermentation when soft wheat flours are used.

The Salt

Salt in amounts up to 2 per cent of the flour improves not only the flavor but also the grain, texture, and the color of bread. The favorable effects on grain and texture derive from its action in stabilizing yeast development and in toughening the dough. The latter action tends to prevent the gluten cell walls from breaking down to form large holes as a result of the softening which other factors produce during fermentation. The specific influence of salt has been attributed to its inhibition of proteolytic enzymes.[84]

The Liquid

The liquid in yeast bread may be water, potato water, or milk. The proportion of liquid which will give bread of good quality and a dough that handles well varies with the particular flour. Thus

[84] Miller and Johnson, *Baker's Digest*, 21: 111 (1947).

very weak flours will absorb only about half their weight in water, strong flours up to about two-thirds. Preferred bread flours average 60 to 65 per cent water absorption. To some extent, the proportion of liquid may be varied to control the length of the fermentation period without altering the quality of the bread. In general, stiffness in doughs retards yeast growth and hence lengthens the period of fermentation required; slackness in the dough has the opposite effect.

The kind of liquid, as well as the amount, affects bread quality. Potato water stimulates yeast growth and is particularly desirable in the sponge type of mixing. Milk (fluid or dried) adds to food value, but its effect on the bread quality depends upon whether it has been preheated. Unheated milk has a dough-softening action that is removed by heating to about 167 degrees F. (75 degrees C.).[85] The effect of heat on the milk proteins is thought to be the principal change reducing the unfavorable action, but the nature of the reaction is not known.

The Sugar

Sugar is added in small amounts to stimulate early yeast growth and to supplement the relatively low level of amylolytic activity in the unheated dough. Early increases in yeast growth also result in greater gas production throughout fermentation, particularly during the critical prebaking stage. An amount of sugar equal to at least 2 per cent of the flour is needed for optimum effect.[86] More is recommended with soft-wheat flours to speed up fermentation.

The Shortening

The addition of shortening up to 3 or 4 per cent of the flour in bread increases loaf volume and makes the texture softer and more velvety. The latter effect is persisting, resulting in improved keeping quality. Fat also increases the sheen and tenderness of the crumb.[87]

The Technics of Manipulation

The essential steps in bread making include the preliminary mixing, fermentation, and the several operations of punching, kneading,

[85] Skovholt and Bailey, *Cereal Chem.*, 12: 307 (1935). Larson et al., *Cereal Chem.*, 26: 189 (1939). Larson et al., *Cereal Chem.*, 29: 440 (1952).

[86] Heald, *Cereal Chem.*, 14: 481 (1937). Baker and Mize, *Cereal Chem.*, 19: 84 (1942).

[87] Carlin, *Baker's Digest*, 21: 78 (1937).

cutting, and folding for the pans after fermentation has progressed. These latter operations are very important in controlling bread quality. Even experienced workers find it difficult to secure uniform results among themselves or on successive loaves of their own preparation, principally because of variations in handling, since other factors are more controllable. A final rapid fermentation period when the dough is in the baking pan is called *proofing*. Procedures in bread making may vary greatly and yet give satisfactory results, but the above steps outline the general procedure.

The Preliminary Mixing

Mixing may be by the straight dough process, in which all the ingredients are added at once, or by the sponge process, in which part of the flour, and sometimes part of the other dry ingredients, are withheld until there has been a period of fermentation. The principal functions of the preliminary mixing of the flour ingredients are the development of the gluten and the incorporation of all ingredients in a dough of uniform consistency. As the liquid comes in contact with the protein particles, it is quickly imbibed. The swollen proteins make contacts and a gluten gel is formed. The flour particles lose their identity, and starch, yeast, and fat are dispersed in the gluten. The more evenly the liquid is distributed, the more uniform is the gel development. If too much liquid is added, the water films on the gluten particles are thick, contacts are loose, and the dough is so slack that it will stretch too easily. If insufficient liquid is added, the dough will be stiff and inelastic. Thus, the proper degree of extensibility of a dough requires the presence of an appropriate amount of water which is distributed uniformly.

Mixing to the proper degree is a very important factor in the final quality of the bread. Doughs which are undermixed or overmixed at this stage produce bread which has low volume, coarse grain, and a streaky crumb. Properly mixed doughs from strong flours cohere to form a continuous elastic mass, but mixing of doughs made from weak flours must be stopped while the dough is still somewhat slack and sticky. In undermixed doughs, the liquid and other ingredients are not uniformly distributed and the gluten is underdeveloped. In overmixed doughs, the cohesive quality of the gluten is reduced, probably by breaking the brush-heap fibers. In either case, the capacity of the dough for extension is reduced.

When bread is mixed in the household, especially when it is mixed

by hand, there is probably more danger of undermixing than of overmixing, except when soft-wheat flour is used. Thorough mixing is more difficult with the straight dough process than with the sponge process, and special precautions should be taken to make it adequate.

Fermentation

The fermentation period in bread making is the time during which enzyme activities are in progress. The tendency is to emphasize the role of amylases and yeast enzymes, but proteinases may also have significant effects, particularly when present in the amounts provided by enzyme supplements added in commercial baking.[88] As soon as moisture is added to the yeast-flour mixture, the chain of enzymatic reactions beginning with the transformation of starch to dextrins and ending with the production of carbon dioxide is initiated. The corresponding chemical nature of proteolytic activity is relatively unknown.

The characteristic changes during fermentation of a dough include foam formation and the resulting increase in volume, increase in acidity, and softening or maturing of the gluten. Foam formation causes increase in volume and lightness and fineness of grain. The gluten strands are pulled into thin-walled cells by the pressure of the carbon dioxide bubbles. If the gluten is weak, it will break and leak before the bubble expands to a desirable size. It is thought that the gluten walls must be continuous to retain the gas, and hence the starch granules are embedded in the wall with no exposed surfaces.

The increase in acidity or hydrogen-ion concentration is likewise due principally to the carbon dioxide, but organic acids such as lactic and acetic acids are also formed. Fermenting bread doughs commonly reach a *p*H of about 5.5 or less. The increased acidity is advantageous because it promotes amylolytic activity and yeast growth, and also because it tends to retard the development of undesirable kinds of bacteria.

Direct effects of the increased acidity upon the properties of the gluten are not so well understood. As fermentation proceeds, the gluten reaches a peak of tenacity after which this quality diminishes. The changes that take place in the gluten are known as ripening or maturing. They are believed to result from alterations in the colloidal nature of the gluten particles, but whether they are caused

[88] Johnson and Miller, *Baker's Digest*, 26: 45 (1952).

by proteolytic enzymes, the constant stretching, or other factors acting alone or in combination has not been determined. A properly matured dough can be defined as one which has developed maximum elasticity and hence maximum capacity to retain gas.

Two factors are of especial importance during the fermentation period: (1) the rate of fermentation, and (2) control of the amount of fermentation.

The Rate of Fermentation. Factors affecting the rate of yeast growth in dough are the initial quantity of the yeast, the fermentation temperature, and the food supply. The more yeast added to the dough at the beginning, the more rapid is the fermentation, but there is an upper limit to the proportion which gives desirable texture and taste.

Yeast will grow well over a range of 74 to 100 degrees F. (23 to 38 degrees C.), the range of the most rapid development being from 84 to 95 degrees F. (29 to 35 degrees C.). The total fermentation period includes the time after mixing begins until the dough is shaped into loaves and put into the pans, the time the dough is in the pans before it is placed in the oven—that is, the proofing period—and the time in the oven before the thermal death point of the yeast is reached. Under commercial conditions, the preliminary fermentation is carried out at temperatures of 74 to 81 degrees F. (23 to 27 degrees C.), and the proofing at 95 to 98 degrees F. (35 to 37 degrees C.), though a considerably wider range may give satisfactory products.[89] The BHNHE recommends temperatures between 80 and 85 degrees F. (27 and 30 degrees C.) for dough fermentation in the household. Somewhat lower temperatures may be employed with the sponge process. Fermentation is exceedingly rapid during the first part of the baking period, causing the increase in volume known as *oven spring*, which will be discussed in connection with baking.

So far as essential nutrients for yeast growth are concerned, sugar is the principal limiting ingredient. The amount present depends not only upon the small quantity in the flour and that added as an ingredient but also upon amylolytic activity as explained in the section on leavening agents. Commercially, malt and other yeast foods are commonly added.

Control of the Amount of Fermentation. During fermentation, the gas vesicles grow in size. At first, little carbon dioxide is lost to the atmosphere, but there comes a point at which the surface bubbles

[89] Pyler, *Baking Science and Technology*, Siebel Publishing Co., Chicago, 1952, Vol. I.

burst their retaining walls. Finally, if the sugar supply is adequate, a stage is reached when the loss of carbon dioxide equals the production. This means that the gluten strands have become very thin and weak. It is therefore very important that the proper stages for making the dough into loaves and for baking be recognized. Even under commercial conditions, where all stages of bread making are well standardized, the time that a dough should ferment is still largely a matter of personal judgment. Under household conditions, this is an exceedingly critical period because the cultivation of expert judgment requires experience, and because the environmental conditions for the dough during fermentation are less carefully controlled.

The range in fermentation times which produces bread of at least standard quality is known as the *fermentation tolerance* of a flour. Low fermentation tolerance in some flours is caused by sugar exhaustion and poor gas formation. The gas production reaches a maximum before the gluten is sufficiently ripe to stretch the desired amount. Low fermentation tolerance in other flours is a result of the maturing of the gluten before maximum gas production is reached. By the time that gas production has reached a high level, gas retention has become deficient. Flours which make doughs in which the proper degree of gas production and of ripening develop simultaneously have a high fermentation tolerance. As noted previously, commercial bakers often increase the fermentation tolerance of flour by adding certain chemical improvers to increase gas retention, or by including amylases in some form if gas production is deficient. Under well-controlled conditions, flours with poor fermentation tolerance may produce good bread. High-grade flours for household use have a high degree of fermentation tolerance produced by blending and other mill processes.

Strong flours both tolerate and require more fermentation than weak. Very weak flours produce doughs that offer little resistance to fermentation and result in flat loaves. The stronger the flour, the easier it is to produce bread of uniform quality from day to day, because the dough will stand a wider range in the length of the time for fermentation. In one study of the effect of prolonged fermentation, it was found that low-grade flours produced good bread over a range of only 5 minutes' variation in their fermentation periods, whereas an 85 per cent patent flour gave good bread over a range of 30 minutes in fermentation periods.[90]

[90] Clark, *Cereal Chem.*, 6: 338 (1929).

Dough must be baked, therefore, before it has reached the stage when carbon dioxide loss equals production or there will be poor oven spring (expansion) and perhaps falling, whatever the original strength of the gluten. Weak glutens (soft-wheat flours) reach the stage where gas loss equals gas production more quickly than do strong glutens, and their fermentation must be regulated accordingly. If bread is baked before this balance between gas production and loss is sufficiently close, the gluten will not leak enough during oven spring, and the loaf cracks or "rips." The adequacy of the fermentation period may be judged from other qualities in the bread. Overfermented bread has a coarse grain, pale crust, a worm-eaten appearance on bottom and sides, and a sour odor. The sourness is due principally to the overproduction of lactic acid. Underfermented bread is heavy and soggy, with thick-walled cells. The loaves have smooth sides and sharp edges. Both underfermented and overfermented doughs give loaves of small volume.

Manipulation after Fermentation Has Progressed

In the making of bread, certain amounts of punching and kneading are applied to the dough at various stages of fermentation. The type of mixing motion is important. Stretching and folding improve the dough, but cutting and tearing damage it. The optimum quantity of such manipulation varies with the type of flour and other factors. It serves the following functions:

1. It expels excess gas and other volatile fermentation products. Yeast cells develop unevenly. Removal of some of the carbon dioxide prevents excessive stretching of certain gluten strands before others have been stretched enough to give fine-walled cells.
2. It equalizes the temperature throughout the dough mass; naturally this promotes uniform development of the yeast.
3. It incorporates air, the oxygen of which is essential for yeast growth.
4. It distributes the yeast cells and their food evenly. This again promotes uniformity in their development.
5. It subdivides the gas bubbles, giving uniformity and fineness to the grain.

In general, punching greatly prolongs the period of high gas production. It also unites the strands of gluten so that they are capable of greater stretching. This results in the formation of larger gas cells with very thin walls. Two punchings with three rising periods

before panning improve quality in bread made from strong flours.

Unless a weak flour is being used, overkneading is probably not a common cause of poor quality in homemade bread. Prolonged or vigorous manipulation after fermentation has progressed may, however, reduce the capacity of the dough for extension more readily than in the preliminary mixing. Treatment should be especially light when the dough is being prepared for the pans to prevent the reuniting of thin gluten walls, which would result in coarseness in the bread.

After fermentation in the dough mass has reached the proper stage, the dough is shaped into loaves and placed in lightly greased pans in amounts that fill the pan about half full. The succeeding period of fermentation, proofing, should be carried out at a somewhat higher temperature than that for the previous fermentation to produce the best quality in the finished product. Temperatures that are too high cause uneven fermentation and loss of flavor, and those that are too low cause coarseness in the bread.

The Baking

About 400 degrees F. (200 degrees C.) is recommended for household bread baking, but the temperature chosen should depend upon the size of the loaf.[91] The optimum temperature varies also with the type of the dough and the processes by which it was made. While a loaf is being baked, the interior temperature approaches the boiling point of water. Near the surface, as the crust forms and dries out, the temperature becomes somewhat higher. The principal results of the heat of baking are:

1. Increased gas production and expansion in the first part of the baking period.
2. The death of the yeast, destruction of the enzymes, and termination of fermentation.
3. The partial gelatinization of the starch, formation of pyrodextrins, and browning of the surface.
4. The coagulation of the gluten.

As noted previously, during the first part of the oven period, yeast growth and amylolytic activity are greatly accelerated. The increased gas production, which includes vaporized water and alcohol as well as carbon dioxide, liberation of gas in solution, and gas ex-

[91] Barackman and Bell, *Cereal Chem.*, 15: 841 (1938).

pansion, give a short period of very rapid rising which has been termed oven spring. This increase in volume is facilitated by a temporary softening of the gluten and the formation of many new gas cells. With doughs made from strong flours, increase in volume may amount to 80 per cent. Most of it takes place during the first 10 minutes in the oven before the interior of the loaf reaches 140 degrees F. (60 degrees C.).[92]

In the dough, most of the water is held by the gluten, because its imbibition capacity is greater than that of the unheated starch. Heating reverses the situation. The gluten loses imbibition capacity and the starch gains it, with the result that gelatinized starch becomes the principal water-holding component and the principal structural support to retain gas and maintain loaf volume. There is not enough moisture in bread, however, for the gelatinization of the starch to be complete.

On the surface of the loaf, drying results in crust formation, and the temperatures are high enough for dextrinization of some of the starch and for browning. The color change is believed to be largely the result of the sugar-amino group reaction. The associated flavor change is important in palatability.

Gluten does not have a definite coagulation temperature, but heat alters its structure over a range of temperatures from 120 to 175 degrees F. (49 to 80 degrees C.). Coagulation begins to be perceptible at 165 degrees F.[93] (74 degrees C.). The change is apparent as a loss in imbibition capacity and a hardening that results in fixation of the foam structure.

Proper rate of baking is necessary to produce a loaf with desired characteristics. If the oven is too hot, crust formation is premature and expansion is arrested. If it is not hot enough, there is overfermentation before the yeast is killed, the starch gelatinized, and the gluten coagulated. Such a loaf tends to fall.

"Brown 'n Serve" breads, rolls, and pastries are baked at low temperatures, 275 to 300 degrees F. (135 to 149 degrees C.), but the undesirable oven spring which would normally develop is prevented by using doughs of stiffer consistency which resist excessive expansion in the oven and by slightly reducing the proportion of yeast and sugar or other yeast foods used by the commercial baker. Products are baked as long as possible without the development of crust color and hence are sufficiently rigid to resist falling as they cool.

92 Bailey and Munz, *Cereal Chem.*, 15: 413 (1938).

93 Alsberg and Griffing, *Cereal Chem.*, 4: 411 (1927).

Biscuits

Palatability Standards

Biscuits should double in size during baking to be of optimum lightness. They should have level tops and vertical sides unless they are of the drop type. Their crust should be smooth and an even golden brown in color. The inside portion should contain many small holes and be flaky, that is, be capable of being pulled up in thin sheets. Biscuits should have a pleasing flavor with no hint of alkalinity or bitterness from unbalanced or excess leavening chemicals.

The Ingredients

The essential ingredients of biscuits are flour, liquid, shortening, salt, and baking powder or its equivalent. Pastry, all-purpose, or bread flour may be used with an appropriate variation in amount of shortening. Milk is the preferred liquid, and, in one study, fluid whole-milk biscuits were judged higher in palatability than biscuits made with other forms of milk.[94] If sour milk is used, a portion of the carbon dioxide required for leavening may come from an appropriate proportion of sodium bicarbonate but baking powder is needed also. No research is at hand to give any particular basis for discriminating among shortenings. The slight flavor of lard of good quality is not considered objectionable. The texture of biscuits varies with the proportion of shortening, low shortening giving a spongy, bready type and higher shortening a more compact, tender type.

The amount and kind of chemical leavening agent also affects texture, and it may cause a characteristic flavor. In sections of the country where soda and cream of tartar are still preferred to baking powder, the tendency to use excess soda leaves a residue which gives a noticeably alkaline flavor. (See the section on leavening agents for the correct proportions of soda and acid.) When biscuits are made with the three types of baking powder in proportions recommended by the manufacturer and under comparable conditions, it has been found that there is no noticeable difference in palatability.[95]

[94] Briant and Hutchins, *Cereal Chem.*, 23: 512 (1946).
[95] Briant and Hutchins, *ibid.*

Technics of Manipulation

Biscuits are a soft dough in which the shortening is blended with the dry ingredients by means of a fork or blender. Then all the liquid is added and the whole is mixed with a fork only until a dough is formed. About ten light kneading operations are recommended, the optimum amount varying somewhat with the proportion and kind of shortening, kind of baking powder, and strength of the flour. Kneading helps to develop the gluten, to distribute the mois-

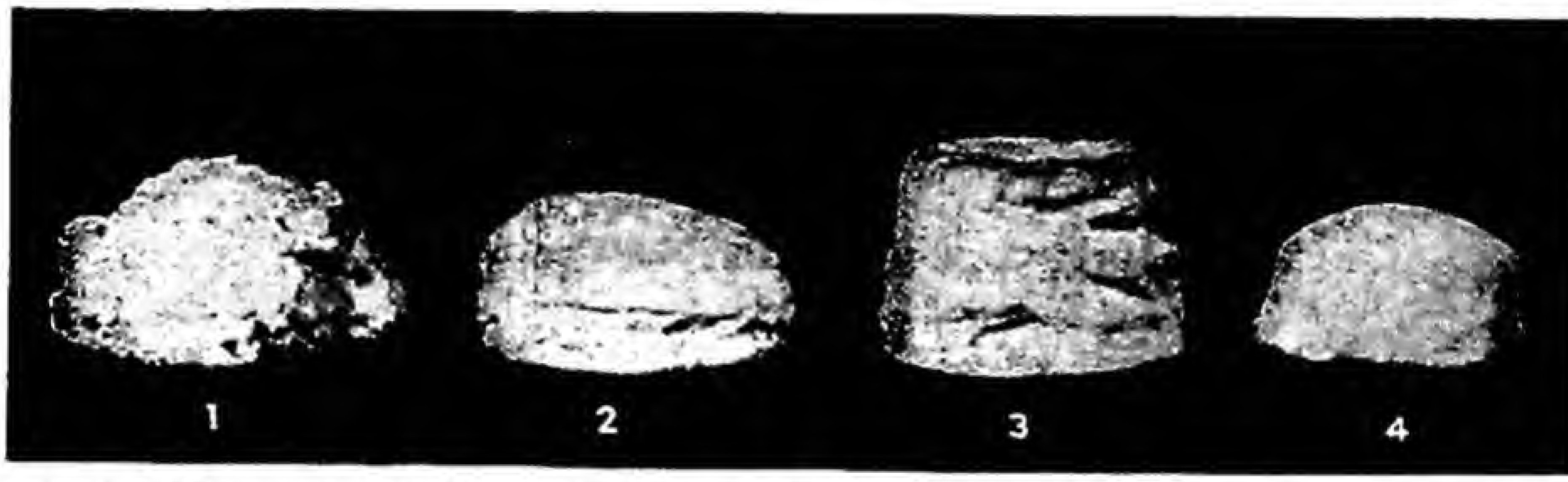

Fig. 46. The relation of the manipulation of the dough to the shape and texture of biscuits. 1. Ingredients stirred until just moistened, dropped on a baking sheet, and baked. 2. Same mixture stirred until just moistened, then rolled, cut, and baked. Note that biscuit is flat and crusty. 3. Same mixture kneaded 18 strokes. Note that biscuit is much taller; interior is flaky, tender, and light. 4. Same mixture overkneaded. Note that biscuit is flat and the interior is tough and close-grained.

ture evenly, and to prevent the brown spots caused by slow solution of soda or phosphates. Extreme overkneading overdevelops the gluten and causes loss of carbon dioxide, changes which may make the biscuits small in volume, close in grain and somewhat tough. (See Fig. 46.) Manipulation of doughs containing strong flours or limited shortening should be relatively restricted. Also, care should be taken to incorporate a minimum amount of flour from the board during rolling and cutting, or the balance of ingredients is disturbed.

Drop biscuits are made from a dough to which extra liquid is added so that it is too soft for rolling. They are preferred by some on account of their thicker, crisper crust. Shortcake, Scotch scones, and dumplings also represent variations from an ordinary biscuit recipe and are mixed according to essentially similar methods. Variety as well as superior nutritive value may also be achieved by the use of whole-wheat flour or small proportions of wheat germ or soy flour.

The Baking

See Table LXI for recommended baking temperatures.

Pastry

Palatability Standards

Piecrust may be flaky or mealy according to the method of distribution of the fat, but it should always be crisp and tender enough to cut easily with a fork. Flaky crusts are covered with blisterlike formations which may be almost entirely absent in the mealy type. A golden brown color on exposed surfaces is preferred.

The Ingredients

The essential ingredients in piecrust are flour, shortening, salt, and liquid. Proportions vary according to the kind of ingredients used and the type of product desired. Commercial bakers often add baking powder to pastry dough because it tends to reduce crust shrinkage.

The Flour

The breaking strength (relative toughness) of pastry increases with the protein content of the flour used, other conditions being similar.[96] Good piecrust may be made with pastry, all-purpose, or bread flour, but stronger flours require more shortening if satisfactory tenderness is to be obtained. Commercial bakers prefer pastry flours or modify stronger flours by addition of cornstarch or rice flour to reduce the proportion of shortening required, because it is relatively expensive. All-purpose flours are often preferred in the household because they tend to give more flaky crusts than pastry flours and the cost of extra shortening is not considered so important.

The Shortening

The kind and amount of shortening used strongly influences the characteristics of piecrust. Oils and melted fats (hot lard, for example) coat a large proportion of the flour particles, interfere with gluten formation, and tend to give a tender, mealy, nonflaky crust.

[96] Denton et al., *Cereal Chem.*, 10: 156 (1933).

To obtain a flaky crust, it is necessary that the shortening be distributed in films between layers of wetted flour in which gluten has been formed. To a certain extent, flakiness and tenderness are incompatible qualities—the greater the number and size of the blisters, the lower is the tenderness. The degree of flakiness is affected by the kind of shortening and technics of manipulation as well as by the kind of flour. Plain lard is generally considered a preferred shortening for either household or commercial use. It combines high shortening power with a satisfactory degree of flakiness. Grainy lards, produced by slow cooling of the freshly rendered fat, favor flakiness because the higher melting grains do not distribute so easily as the softer portions, and tend to remain in layers. Hydrogenated lards and hydrogenated vegetable shortenings, whether the latter are made by partial hydrogenation of the whole product or by a mixture of highly hydrogenated fat with oil, have reduced shortening power but they induce flakiness.

Emulsifiers impair the pastry-making qualities of shortenings because they render them less water-repellent and such shortenings are readily distributed in liquids, qualities which are desirable in cakemaking, however.[97] Almost all manufactured shortenings on the retail market (other than plain lard) are so treated today. Hence, high-quality, hard, grainy lards offer the best choice of shortening for household pie making.

The proportion of shortening specified in household recipes ranges from 3 to 8 tablespoons per cup of flour. The optimum amount depends upon the strength of the flour, the shortening power of the fat, and the type of product desired.

The Liquid

The liquid in pastry may be either water or milk. Nonfat milk solids may also be used. Milk in any form improves crust color. Chilling the liquid is desirable to harden the shortening.

The optimum proportion of liquid in pastry varies with the proportion and consistency of the shortening, with the strength of the flour, and with the method of combining ingredients. When the amount of shortening is constant, too little water results in a crumbly, nonflaky pastry and too much makes it tough, although it may be flaky.

[97] Woerful, *Baker's Digest*, 26: 126 (1952).

TECHNICS OF MANIPULATION

Except in hot-water pie crust, in which the fat is liquefied in the hot water, or the kind made with oil, the shortening in pastry is distributed as in biscuits by blending or rubbing it with the dry ingredients. Thorough mixing increases tenderness, but the optimum amount of mixing depends on the kind of shortening, its temperature, and the degree of mealiness or flakiness preferred. Conditioning the solid fats to room temperature increases tenderness but not flakiness.

Flakiness is promoted by (1) restricting manipulation so that the fat is left in larger pieces, (2) withholding part of the fat for distribution with restricted manipulation (one method is to cut the fat into pea-sized pieces and sprinkle it over the rolled crust which is then folded and lightly rerolled), (3) using harder shortenings such as leaf lard or highly hydrogenated types, and (4) chilling the shortening and liquid before they are incorporated in the flour. Special types of shortening made of tough, waxy, fat which spreads well are available for commercial preparation of puff pastry and similar types which are characterized by an extreme flaky structure.

After the shortening is incorporated in the flour and salt, the method of adding the liquid is a crucial step in obtaining the desired characteristics in pastry. Particularly when shortening is limited or the flour is strong, manipulation to incorporate the liquid should be carefully restricted to prevent the toughness that comes from overdevelopment of the gluten. Sprinkling the water over the blended flour and fat, and perhaps mixing only the amount required for one crust at a time, are desirable practices. Also, it is important that the amount of flour incorporated from the board during rolling be kept at a minimum. The effect on tenderness of rolling out the dough immediately rather than allowing it to stand at room temperature is significantly favorable. This difference is probably related to the amount of hydration of the gluten which has had time to take place, a larger degree of hydration tending to produce less tenderness. A rest period in the refrigerator, however, facilitates rolling and makes the sheet of dough easier to handle.

Overmixing is a common cause of pastry failures. It causes excessive development of gluten and overdisperses the fat, the first decreasing tenderness, and the second, flakiness.

The Baking

In baking two-crust pies the aim is to have the crust properly cooked by the time the filling is done to avoid boiling over of the latter. This is best achieved by using a relatively hot oven. (See Table LXI.) Precooked fillings should be cooled before addition to the dough-lined pan to prevent melting of the shortening in the dough which increases the tendency of the crust to absorb liquid. Cream and custard-type pie fillings may be placed in prebaked crusts, and baked at somewhat lower oven temperatures to prevent overbrowning of the crust.

Griddle Cakes and Waffles

Griddle cakes should have smooth, only slightly pitted, evenly browned crusts on both sides. Waffles should also be evenly browned, but they are much more crisp in texture.

The essential ingredients in griddle cakes are flour, liquid, salt, and a leavening agent. Shortening, egg, or sugar may be added if desired. The proportions of flour may vary from 1¼ to 2 cups per cup of liquid, depending upon the water-absorbing capacity of the flour and the type of product preferred. The dry ingredients are sifted together and then combined with the liquid and slightly beaten egg. Overmixing should be guarded against to prevent excessive loss of carbon dioxide, and, particularly if a relatively thick or unshortened mixture is chosen, to avoid development of gluten.

Shortening is incorporated in the griddle cake batter by liquefying it if it is not an oil, and mixing it with the liquid or liquid-egg mixture before combination with the dry ingredients. In the cooking of griddle cakes, care should be taken to secure a proper temperature of the griddle. If it is too hot, the cakes will stick or be undercooked (runny) on the top side when they are browned on the bottom to a stage requiring turning. They should not have to be turned more than once and must be served while hot for greatest palatability. When shortening is present, it may not be necessary to grease the griddle.

Plain waffles are made from thin griddle-cake batter containing egg and shortening. They should be crisp, tender, and evenly browned. They may be varied by adding more fat and sugar or molasses to give a cakelike product. This type must be baked more

slowly to prevent scorching. It is also possible to bake a shortcake dough of the biscuit type and gingerbread in a waffle iron. When waffles stick, the iron was either too hot or too cold at the time the mixture was added, or the mixture did not contain sufficient shortening.

Popovers and Cream Puffs

Popovers should be crisp and evenly browned and have hollow centers with an interior that is not too moist. Cream puffs and éclairs are similar in general structure, but they should have a tenderer texture.

The essential ingredients of popovers are flour, liquid, egg, and salt. Liquid is used in large proportions, about 1 cup per cup of flour, to furnish the steam required for the desired expansion and for the formation of the hollow interior. The egg supplements the diluted flour in strengthening structure. Popovers are not likely to be made tough by overmanipulation on account of the high degree of hydration of the gluten. A hot oven for the first part of the baking, followed by a diminished temperature, produces rapid expansion in the first period and the proper drying out in the last. (See Table LXI.)

Cream puffs contain proportions of liquid and flour similar to those in popovers, but a comparatively large amount of fat is included to enhance tenderness and more egg is added to emulsify the fat and offset its tendency to weaken the structure. The amount of fat is so large, about $\frac{1}{2}$ cup to each cup of liquid, that it must be cooked with the flour and liquid to keep it in suspension. The eggs are then beaten into the slightly cooled mixture. Baking, as recommended for popovers, consists of a short high-temperature period followed by a period of lower temperature. Éclairs are made from cream puff batter, the difference being in the shape.

Muffins

Muffins should be golden brown in color and symmetrical in shape, with rounded tops and no peaks or knobs. In cross section they should show small, evenly distributed air cells and no long, narrow "tunnels." They should seem large for their weight because this indicates lightness.

Muffins contain flour, liquid, egg, fat, salt, and chemical leavening agent. They are often varied by the substitution of other

flours or meals for all or part of the wheat flour, and by the addition of fruits, nuts, or other ingredients.

A muffin batter is stiffer than those used for griddle cakes and popovers, the proportion of flour to liquid being about two to one by measure. A mixture of this concentration is much more sensitive to manipulation. The method of combining is the same as that employed for griddle cakes, that is, mixing all dry ingredients

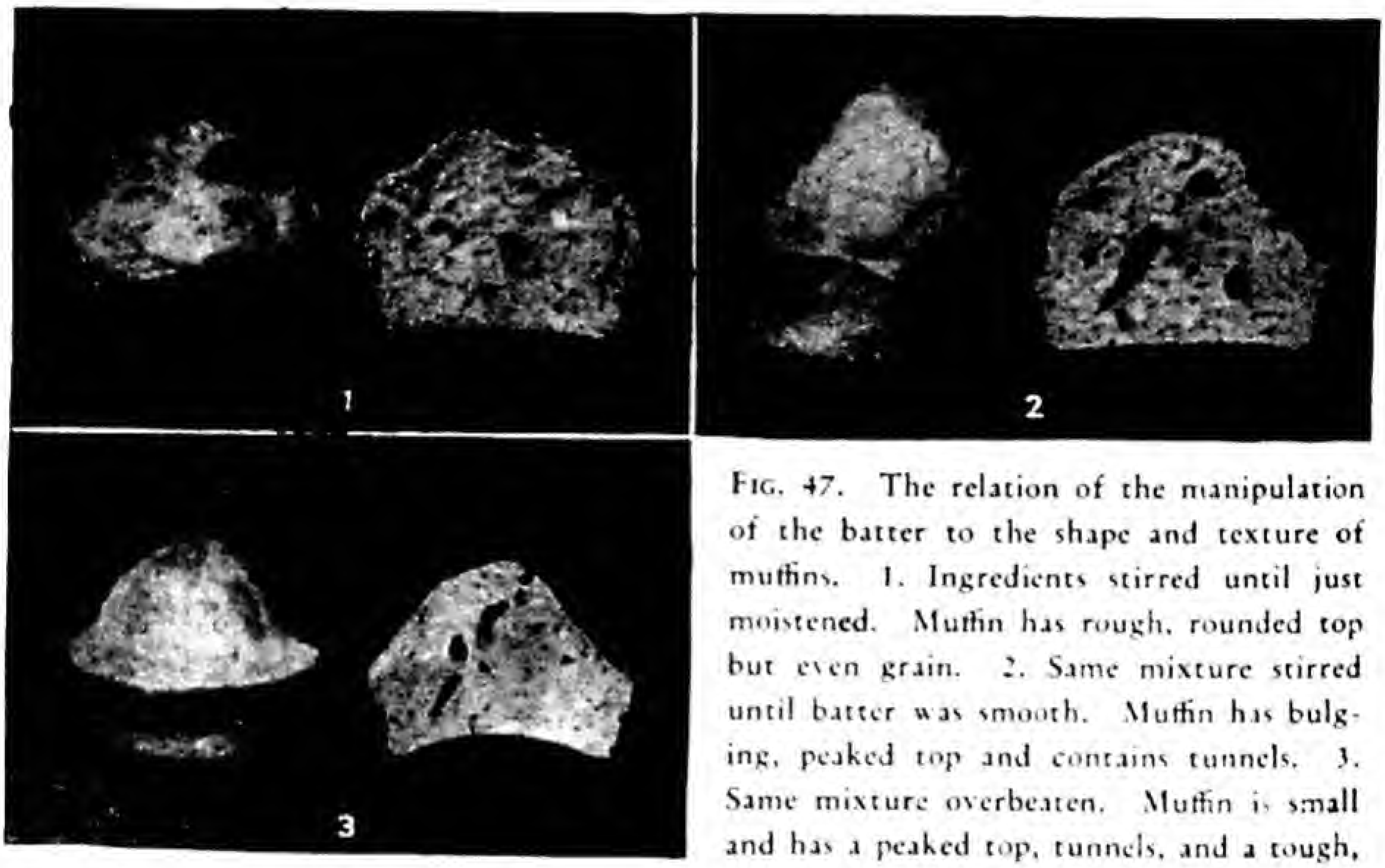

FIG. 47. The relation of the manipulation of the batter to the shape and texture of muffins. 1. Ingredients stirred until just moistened. Muffin has rough, rounded top but even grain. 2. Same mixture stirred until batter was smooth. Muffin has bulging, peaked top and contains tunnels. 3. Same mixture overbeaten. Muffin is small and has a peaked top, tunnels, and a tough, soggy texture.

and all wet ingredients separately before adding the one to the other. In this last step, stirring should be limited to that required for moistening the flour and not prolonged until the batter becomes smooth. Muffins made from overmixed batters develop peaked tops, tunneled interiors, and toughened texture, and, particularly if a rapid-acting baking powder is used, reduced volume. (See Fig. 47.)

Although the proportion of liquid in muffins is too great for formation of the tight continuous gluten structure of a dough, it is small enough to allow the formation of an excessive amount of gluten strands which are responsible for all the characteristics of overmixing except the small volume. This is, at least in part, caused by losses of carbon dioxide, but probably also by increased resistance of the batter. The egg in muffins adds to the structural strength of the gluten and hence increases the effects of overmixing.

It is important to get the muffin batter into the pans quickly before much gas is evolved, but little further loss occurs if it stands a limited period before baking.

The baking temperature should not be too high or the crust will set before sufficient expansion has developed. If the temperature is too low, browning will be retarded until the interior is overdry. (See Table LXI.)

Shortened Cake

Palatability Standards

Shortened cakes are essentially sweet, rich (high in fat) muffins. They should be slightly rounded on top and have a crust that is not sugary. The ideal color varies with the ingredients. The crumb should be moderately fine, moist, and velvety, the air cells numerous, thin-walled, and small, and the flavor characteristic of high quality in the fat and other ingredients which contribute to it.

The Ingredients

Shortened cakes are made from the following basic ingredients: flour, sugar, shortening, egg, liquid, salt, and a chemical source of leavening. Like other flour mixtures, they are foams in structure. Creamed solid shortenings and beaten egg are air foams which must be distributed evenly in the mixture in such a manner as to retain most of the air. The carbon dioxide formed from the chemical leavening agent largely diffuses into the air cells and forms very few new gas pockets.[98] The presence of air is also essential for the functioning of water vapor as a leavening gas.[99] During baking, coagulation of egg and flour proteins and gelatinization of starch confer a rigid structure to the mixture, but one which is tenderized by the waterproofing action of the shortening and the effect of the sugar in dispersing and raising the coagulation temperatures of the proteins.

Literally hundreds of recipes for shortened cakes are in use, and very different ones give acceptable products. In general, the effects of shortening and sugar are antagonistic to those of gluten and egg. Thus, when flour is constant, as fat and sugar are increased, egg must be increased also.

[98] Carlin, *Cereal Chem.*, 21: 189 (1944).

[99] Hood and Lowe, *Cereal Chem.*, 25: 244 (1948).

All shortened cakes may be considered variations of the old household recipe for pound cake, so named because it called for 1 pound each of butter, flour, eggs, and sugar. These proportions give a cake which has relatively low volume, close texture, and high cost. On the basis that flour and egg strengthen structure while fat and sugar weaken it, it has been found that volume can be increased and the relatively expensive shortening decreased if the following general proportions are maintained:

1. Equal weights of shortening and whole eggs.
2. Equal weights of sugar and flour.
3. Combined weight of eggs and milk equal to the weight of sugar or flour.[100]

When modern superglycerinated shortenings are used, the proportions of liquid and sugar should be increased so that:

1. The weight of the eggs is greater than that of the shortening.
2. The weight of the sugar is greater than that of the flour.
3. The combined weight of the eggs and the milk are equal to or slightly greater than that of the sugar.

When the proportions of ingredients in a standard cake recipe were varied under experimental conditions, the following changes in grain, volume, and texture of cakes were found:

Sugar. When the sugar was increased, the grain was coarser and less uniform, the volume slightly larger, and the texture more tender. When it was decreased, the grain was finer, the volume smaller, and the texture slightly tough.

Fat. When the fat was increased, the grain was unchanged, but the volume was slightly smaller, and the texture greasy. When it was decreased, the grain was unchanged or slightly coarse, the volume larger, and the texture harsh.

Liquid. When the liquid was increased, the grain was finer, the volume smaller, and the texture moist and tender. When it was decreased, the grain was coarser and less uniform, the volume larger, and the texture harsh and dry.

Baking powder. When the baking powder was increased, the grain was coarser but uniform, the volume larger, and the texture slightly harsh but tender. When it was decreased, the grain was fine and close, the volume smaller, and the texture slightly soggy.

Thus increasing sugar or baking powder, or decreasing liquid, had similar effects on grain and volume, but the texture that re-

[100] Pyler, *Baking Science and Technology*, Siebel Publishing Co., Chicago, 1952, Vol. II, p. 602.

sulted when baking powder was decreased was preferable to that when liquid was decreased.[101]

Cornell experimenters found that higher proportions of sugar and fat produced cakes with finer, more uniform cell structure and more velvety, tender crumb than lean mixtures, whatever the method of mixing employed.[102]

Variations in the kind of flour and shortening are of great importance in household cakemaking. There is general agreement that cake flours, as a result of their low gluten content and fine particle size, give cakes of superior texture qualities.

Satisfactory cakes can be made with a variety of shortenings, including butter, oleomargarine, lard, oil, and the hydrogenated vegetable shortenings or compounds. However, the method and conditions of combining ingredients as well as the proportions among the ingredients should be adapted to the particular shortening, if best results are to be obtained. In general, the superglycerinated, hydrogenated vegetable shortenings are specialized to produce excellent cakes under perhaps the widest range of conditions. The Cornell experimenters reported that "fat appeared to be the ingredient most influential in determining the amount of air entrapped in the batter and the pattern of ingredient dispersion. Hydrogenated shortening was a good creaming agent and was also readily dispersed in the batters." This shortening was a superglycerinated, vegetable type. It resulted in cakes of good or excellent quality over a wide range of ingredients, temperatures, and methods of mixing.

The favorable effect of an emulsifier has been demonstrated by comparing the palatability of cakes made according to a standardized procedure with butter and hydrogenated vegetable shortening, each with and without added glyceryl monostearate. The emulsifier increased the scores for all qualities rated in cakes made with either shortening, but the emulsified butter cakes were considered the most acceptable.[103]

TECHNICS OF MANIPULATION

The principal problems in combining the ingredients of shortened cakes are the distribution of shortening and the incorporation

[101] Davies, *Cereal Chem.*, 14: 819 (1937).

[102] Hunter et al., *Cornell Expt. Sta. Bull.* 860 (1950).

[103] Jooste and Mackey, *Food Res.*, 17: 185 (1952).

of beaten eggs so that there is little loss of air. When the shortening is evenly dispersed in the batter, the cake tends to be fine-textured, tender, and velvety. The kind of fat, how it is dispersed, the proportions of other ingredients, the temperatures at which ingredients are combined, all affect fat distribution.

Methods of mixing cakes which have received the most attention are of four basic types, (1) the conventional method, (2) the "quick" method, (3) the pastry-blend method, and (4) the muffin method. The first three are employed with solid shortenings and the fourth with melted fat or oil. No doubt other methods will continue to be devised which have advantages under particular conditions. One of the latest to be suggested is a sugar-water batter method. The sugar plus one-half of its weight in water are stirred together first. Other ingredients, except the rest of the water, whole eggs, and flavoring, are added as a second step. Finally, addition of the rest of the water, whole eggs, and flavoring makes a three-stage procedure which is said to give better emulsification and aeration, better crust color, higher volume, and finer grain than the usual commercial "quick" method.[104]

The Conventional Method

The conventional method of combining cake ingredients consists of creaming the fat to incorporate air and increase its plasticity, adding the sugar gradually with accompanying stirring, and then incorporating the beaten whole eggs or yolks. Next, the sifted remaining dry ingredients and liquid are added in alternate portions while mixing is continued. When egg whites have been beaten separately, they are folded in last. Under household conditions and without the use of a power mixer, this method, when skillfully performed, yields cakes with a velvety crumb which retain their fresh qualities well. It is still a preferred method if the shortening used is butter or margarine because the creaming stage incorporates air effectively and increases plasticity, which favors dispersion, but the method is laborious and time-consuming and not adapted to soft lard or oils.

A modification of the conventional method called the *conventional-sponge* method gives good cakes with all fats but is particularly successful with soft lards as compared with the straight conventional method. The shortening is creamed with half the

[104] Stateler, *Food Inds.*, 22: 1180 (1950).

sugar and the salt. Then the flour, sifted with the baking powder, and the milk are added in alternate portions. Finally the rest of the sugar, which has been beaten with the egg to form a spongy batter, is quickly folded into the prepared mixture.

The creaming temperature of the shortening affects both the amount of air incorporated into the fat and the dispersion of the fat in the other ingredients. Hydrogenated shortenings both cream and disperse well over a wide range of temperatures. Lard does not cream well although it disperses readily. Cakes made with it are said to be best when ingredients are at about 72 degrees F. (22 degrees C.).

In general, the conventional method of mixing cakes requires considerable skill, energy, and time, particularly if the mixing is by hand. The optimum amount of mixing varies with the proportions of ingredients and is difficult to specify. Too much mixing makes the cake compact and may produce tunnels. However, in the hands of experts, the texture usually surpasses that obtained by any other method in fine-grained uniformity and velvetiness of crumb.

The "Quick" Method

This method is also called the "beating," "single stage," "one-bowl," "dump," or "speed" method. For some years, it has been recognized that it is possible to make satisfactory cakes with a power mixer by a single-stage method in which all ingredients except the leavening agent are placed in the mixer before any attempt is made to combine them. After an amount of mixing, varied to suit the proportions of the recipe, the leavening agent is added and the mixer run for another minute or two. It is usually advantageous to beat the egg whites separately and fold them in at the end. Optimum results require having shortening and other ingredients warmed to room temperature.

With the development of superglycerinated shortenings, this single-stage method has been modified to make a two-stage procedure for use with either hand or power mixing, which has been widely adopted in the household. The shortening and dry ingredients are mixed with part of the milk by beating for 2 minutes. Then the remaining milk and the eggs are incorporated by a second 2 minutes of mixing. For uniform results it is important to time the mixing accurately or, in hand beating, to count the strokes as specified in the recipe. Double-acting baking powder may be incorporated in the dry ingredients, but others should be added in the

second stage. This method works best when all ingredients are at room temperature to facilitate distribution of the fat. Recipes specifying medium or high proportions of sugar and fat give better products than do lean recipes. "Quick" method cakes are light and feathery in texture and sweet and rich in flavor. Also they are moist and have excellent keeping quality. Several advantages over the conventional method of cake mixing make this method very popular; some of these are the less skill, the shorter time, and the fewer utensils required. It is not suitable for use with butter, margarine, or plain lard.

The Pastry-Blend Method

In the pastry-blend method, the fat and flour are creamed together to distribute the fat and form a foamy mass. Then the sugar, salt, baking powder and half of the milk are blended into this mixture, followed by incorporation of the rest of the milk and the egg. A similar method, called a *flour-batter* method, is widely used in commercial cake production, but is relatively unknown in the household. According to the Cornell experiments it might well be adopted because it is suited to a wider range of ingredients and conditions for the production of high-quality cakes than the conventional method. It was found to give particularly good results as compared with the conventional method, with either lard or margarine as the shortening.

The Muffin Method

As the name indicates, this method consists of combining the liquid and dry ingredients after they have been mixed separately. The shortening which is either melted fat or oil, is incorporated with the liquid. This is the quickest and easiest method of making cake, but in its simplest form gives a product of rather coarse texture which loses its freshness rapidly. Cakes made with liquid shortening can be markedly improved in eating quality by preparing a stiff meringue of the beaten egg whites and one-fourth of the sugar. This is blended in as a last step in the mixing.[105] Presumably the stabilization of the foam by the sugar causes the air to be better retained during the mixing and reduces loss of volume during baking. The recently popularized "chiffon" cakes made with salad oils are mixed by what is essentially the muffin method with a meringue stabilized by beating the egg whites to a *very stiff*

[105] Ohlrogge and Sunderlin, *J. Am. Dietet. Assoc.*, 23: 213 (1948).

stage with cream of tartar. The remaining ingredients are thoroughly mixed and carefully blended into the beaten whites as a last stage.

The muffin method has also been successfully adapted for use with liquid lard and called a "hot-lard" method.[106] The whole eggs, sugar, and salt are beaten until thick and creamy. Half of the sifted dry ingredients (flour or, if all-purpose flour is used, flour and cornstarch, and baking powder) are added with half the milk. When the mixture is smooth, the remaining half of each is incorporated. Finally the melted lard is stirred in rapidly and the mixture transferred to a pan and baked immediately. This method of combining is said to be particularly successful in masking slight rancidity in lard.

In general, the palatability of cakes does not depend upon the time required for mixing them.[107] Perhaps the most important factor in the choice of method is to have the appropriate kinds and proportions of ingredients at a suitable temperature. Varying the basic method of combining ingredients specified in a particular recipe does not yield uniform results.

The Baking

Cake batters do not retain evolved carbon dioxide well and hence should be placed in the baking pans immediately when mixing is finished. Retention of the gas is also favored by baking at temperatures which are adjusted to give a proper balance between the development of structural rigidity and gas production. In the Jooste-Mackey experiments with emulsified shortenings it was found that 425 degrees F. (218 degrees C.) gave products that had higher volume and superior texture in comparison with those baked at 300, 325, or 375 degrees F. (149, 163, or 191 degrees C.). The explanation given was that the higher temperature caused earlier coagulation of the cake proteins and thus facilitated gas retention. Perhaps the same reason, more rapid heat penetration speeding up coagulation, explains why baking in shallow pans tends to result in better cakes than baking in deeper pans of the same volume.[108] It would seem that the temperatures for baking shortened cakes recommended in Table LXI might well be revised upward.

[106] Baeder, *Nebr. Agr. Expt. Sta. Res. Bull.* 320 (1938).
[107] Tinklin and Vail, *Cereal Chem.*, 23: 155 (1946).
[108] Charley, *J. Home Econ.*, 44: 115 (1952).

Unshortened Cake

Palatability Standards

Unshortened cakes are of three major types: sponge, containing whole eggs; angel food, containing the whites only; and sunshine, containing more whites than yolks. These cakes should be light, tender, and easily pulled into pieces. A cross section should show uniform, medium-sized cells.

The Ingredients

In the number of ingredients, unshortened cakes represent one of the simplest types of flour mixtures. Essential components are egg, flour, sugar, and salt. The leavening is produced primarily by the air in the beaten egg, which expands during heating. As mentioned previously, the batter is usually slightly acidified with cream of tartar or some other acid because it whitens the flour—a factor of importance in angel food cakes—improves the stability of the foam, and increases the tenderness of the final product by lowering the coagulation temperature. Factors affecting the quality of beaten egg whites were discussed in Chapter 11.

The egg foam constitutes the principal structural element in unshortened cakes and the degree of tenderness depends upon the proportion of sugar when other conditions are constant. Increasing the proportion of sugar increases tenderness, whereas increasing the proportion of flour diminishes it. Cake flour is the preferred type.

Technics of Manipulation

Important factors of manipulation which affect volume and texture of unshortened cakes are the whipping of the eggs, especially the whites, the method of combining ingredients, and the extent of the mixing. For these cakes, the egg white should be whipped sufficiently to give a stable foam of satisfactory volume but not so much that it becomes overcoagulated and inelastic. The most accurate method of judging the degree of whipping and maintaining uniformity is to measure the specific gravity of the foam. Foams with a specific gravity between 0.150 and 0.170 are said to be best for

angel food cake.[109] This is a stage at which the foam is stiff but not dry.

Several methods of combining the ingredients of unshortened cakes give satisfactory products. They include (1) adding all the sugar to the beaten egg whites, or to the whites and yolks beaten separately and blended, and then adding the flour, (2) adding one-half of the sugar to the beaten eggs, and the remainder with the flour, (3) adding all the sugar with about one-third of the flour to the beaten eggs first and then the remaining flour, (4) making a sirup of the sugar by cooking it with half as much water to a temperature of 248 degrees F. (120 degrees C.), pouring this over the stiffly beaten whites, adding the beaten yolks, and, last, the flour, and (5) adding the sugar and the flour sifted together or in alternate portions. Halliday and Noble recommend the second method, but Barmore, Lowe, and Stanley and Cline prefer the first method. The addition of the sugar to the egg-white foam before adding any flour seems to strengthen it so that it is possible to incorporate the flour with smaller loss of volume. When the sugar is added first to the egg foam, it may be beaten for 30 seconds with a power beater; then the flour should be stirred into the mixture with just enough manipulation to secure even distribution throughout the batter. Angel food cakes are generally better when mixed by a method in which at least part of the sugar, either dry or as a sirup, is added to the whites before the flour.

The Baking

Baking temperatures often recommended for unshortened cake range from 300 to 350 degrees F. (149 to 177 degrees C.) for 45 to 60 minutes, but 355 degrees F. (179 degrees C.) for 30 minutes is said to produce a more tender cake of larger volume. In this period, the maximum temperature within the cake is not much different from that at lower temperatures for a longer time.[110] (See Table LXI.)

Cookies

Cookies should be evenly browned on both sides. They vary in texture from the crispness of refrigerator types to the softer, cake-

[109] Barmore, *Colo. Agr. Expt. Sta. Bull.* 15 (1936).
[110] Barmore, *op. cit.*

like texture of dropped types, but they should not be either tough or breadlike.

Recipes for cookies are essentially shortened cake recipes altered to contain less liquid and usually less sugar. Drop cookies contain a larger proportion of liquid than the roll type. In making the latter, it is very important to incorporate as little as possible additional flour from the board during rolling. In fact, in one study it was discovered that rolling without flour produced sugar wafers with a breaking strength only a little more than half that of wafers rolled with the minimum amount of flour to prevent sticking. Beating extra flour into the dough gave a more tender product than incorporating the same amount during rolling.[111] Evidently the latter does not become coated with shortening effectively. Refrigerator cookies are made from doughs hardened in the refrigerator so that they may be sliced rather than rolled, thus avoiding the problem of rolling without incorporation of additional flour. Breaking strength in crisp cookies does not necessarily control preference for them, however. For example, butter as a shortening gives cookies with a higher breaking strength than oils, lard, or hydrogenated shortenings, but, on account of flavor or other reasons, most people prefer those made with it.[112]

See Table LXI for recommended baking temperatures.

Doughnuts

Doughnuts are made from a dough similar to that used for drop cookies but modified to contain less shortening and sugar. The fat content is increased by absorption during frying. They should be well-browned, light in texture, and free from visible penetration of the frying fat into the outer layers.

The most important problem in the making of doughnuts of high quality is the restriction of fat absorption during frying. Lowe states that the following factors control this property: (1) the length of time of cooking, (2) the temperatures of the frying fat, (3) the surface area of the food, and (4) the proportions of ingredients and the methods of manipulating them.

In general, doughs continue to absorb frying fat as long as they remain in it. Consequently, this time should be minimized by the use of small portions and relatively high temperatures. The tem-

[111] Noble et al., *Cereal Chem.*, 11: 243 (1934).

[112] Lowe and Nelson, *Iowa Agr. Expt. Sta. Res. Bull.* 255 (1939).

perature of the fat should be as high as will produce thorough cooking in the time required for adequate surface browning. Of course, the larger the surface, the greater the fat absorption tends to be; hence irregularities of surface should be avoided.

Among the more important variations in ingredients affecting fat absorption are the proportions of fat, sugar, and liquid. The larger the proportion of any of these, the greater the fat absorption. The amount of mixing and the method of combining may alter fat absorption somewhat. See Chapter 13 for discussion of cooking in deep fat.

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APPENDIX

FOOD VALUES IN COMMON PORTIONS

This compact food composition table, for reference use in class work and meal planning, will enable nurses, clinicians, extension workers, and students to compare quickly the nutritive value of foods and to estimate the nutritive value of diets.

Data are given in quantities that can be readily adjusted to servings of different sizes. Values for prepared foods and food mixtures have been calculated from typical recipes. Values for cooked vegetables are without added fat.

A table showing recommended amounts of key nutrients is included; it is adapted from the recommended daily allowances of the Food and Nutrition Board of the National Research Council.

The following abbreviations are used: gm. for gram; mg. for milligram; IU for International Unit; cal. for calories; Tr. for trace. Ounce refers to weight; fluid ounce to measure.

Table 1. Nutrients in household quantities of foods °

Food and approximate measure or common weight	Water, %	Food energy, cal.	Protein, gm.	Fat, gm.	Total carbohydrate gm.	Calcium, mg.	Iron, mg.	Vitamin A value, IU	Thiamine, mg.	Riboflavin, mg.	Niacin value, mg.	Ascorbic acid, mg.
Milk and Milk Product,												
Buttermilk, from skim milk, 1 cup	90	85	9	Tr	12	288	0.2	10	0.09	0.43	0.3	3
Milk, cow												
Fluid, whole, 1 cup	87	165	9	10	12	288	0.2	390	0.09	0.42	0.3	3
Fluid, nonfat (skim), 1 cup	90	85	9	Tr.	13	303	0.2	10	0.09	0.44	0.3	3
Evaporated (undiluted), 1 cup	74	345	18	20	25	612	0.4	1010	0.12	0.91	0.5	3
Condensed (undiluted), 1 cup	27	980	25	26	168	835	0.6	1300	0.16	1.19	0.6	3
Dry, whole, 1 tablespoon	4	40	2	2	3	76	0	110	0.02	0.12	0.1	1
Dry, nonfat solids, 1 tablespoon	4	30	3	Tr.	4	98	0	Tr.	0.03	0.15	0.1	1
Milk, goat, fluid, 1 cup	87	165	8	10	11	315	0.2	390	0.10	0.26	0.7	2
Cheese, 1 ounce												
Cheddar (1-in. cube)	37	115	7	9	1	206	0.3	400	0.01	0.12	Tr.	0
Cheddar, processed	40	105	7	8	1	191	0.3	370	Tr.	0.12	Tr.	0
Cheese foods, Cheddar	43	90	6	7	2	162	0.2	300	0.01	0.16	Tr.	0
Cottage, from skim milk	76	25	6	Tr.	1	27	0.1	10	0.01	0.09	Tr.	0
Cream	51	105	3	10	1	19	0.1	410	Tr.	0.06	Tr.	0
Swiss	39	105	8	8	Tr.	262	0.3	410	Tr.	0.11	Tr.	0
Cream, 1 tablespoon												
Light	72	30	Tr.	3	1	15	0	120	Tr.	0.02	Tr.	Tr.
Heavy	59	50	Tr.	5	Tr.	12	0	220	Tr.	0.02	Tr.	Tr.
Beverages, 1 cup												
Chocolate (all milk)	80	240	8	12	26	260	0.5	350	0.08	0.40	0.3	2
Cocoa (all milk)	79	235	10	12	27	298	1.0	400	0.10	0.46	0.5	3
Chocolate flavored milk	83	185	8	6	26	272	0.2	230	0.08	0.40	0.2	2
Malted milk	78	280	12	12	32	364	0.8	680	0.18	0.56	....	3

Desserts												
Blanc mange, 1 cup	76	275	9	10	39	290	0.2	390	0.08	0.40	0.2	2
Custard, baked, 1 cup	77	285	13	13	28	283	1.2	840	0.11	0.49	0.2	1
Custard pudding, canned, strained (infant food), 1 ounce	75	30	1	1	5	26	0.1	60	Tr.	0.04	Tr.	Tr.
Ice cream, plain												
1/7 of quart brick	62	165	3	10	17	100	0.1	420	0.03	0.15	0.1	1
8 fluid ounces	62	295	6	18	29	175	0.1	740	0.06	0.27	0.1	1
Fats, Oils, Related Products												
Bacon, medium fat, broiled or fried, 2 slices	13	95	4	9	Tr.	4	0.5	0	0.08	0.05	0.8	0
Butter, 1 tablespoon	16	100	Tr.	11	Tr.	3	0	460 †	Tr.	Tr.	Tr.	0
Fats, cooking (vegetable fats)												
1 cup	0	1770	0	200	0	0	0	0	0	0	0	0
1 tablespoon	0	110	0	12	0	0	0	0	0	0	0	0
Lard, 1 tablespoon	0	125	0	14	0	0	0	0	0	0	0	0
Margarine, 1 tablespoon	16	100	Tr.	11	Tr.	3	0	460 ‡	0	0	0	0
Oils, salad or cooking, 1 tablespoon	0	125	0	14	0	0	0	0	0	0	0	0
Salad dressings, 1 tablespoon												
French	40	60	Tr.	5	3	0	0	0	0	0	0	0
Home-cooked	68	30	1	2	3	15	0.1	80	0.01	0.03	Tr.	Tr.
Mayonnaise	16	90	Tr.	10	Tr.	2	0.1	30	Tr.	Tr.	0	0

* AIB-36. Adapted from the more comprehensive tables in "Composition of Foods—Raw, Processed, Prepared," by Watt and Merrill, *Agriculture Handbook* No. 8, 1950, United States Department of Agriculture. By permission of the BHNHE.

† Year-round average.

‡ Based on the average vitamin A content of fortified margarine. Most margarines manufactured for use in the United States have 15,000 IU of vitamin A added per pound; minimum Federal specifications for fortified margarine require 9000 IU per pound.

Table 1. Nutrients in household quantities of foods—*Continued*

Food and approximate measure or common weight	Water, %	Food energy, cal.	Protein, gm.	Fat, gm.	Total carbohydrate, gm.	Calcium, mg.	Iron, mg.	Vitamin A value, IU	Thiamine, mg.	Riboflavin, mg.	Niacin value, mg.	Ascorbic acid, mg.
Eggs												
Eggs, raw, medium												
1 whole	74	75	6	6	Tr.	26	1.3	550	0.05	0.14	Tr.	0
1 white	88	15	3	0	Tr.	2	0.1	0	0	0.08	Tr.	0
1 yolk	49	60	3	5	Tr.	25	1.2	550	0.05	0.06	Tr.	0
Eggs, dried, whole, 1 cup	5	640	51	45	3	205	9.5	4,040	0.36	1.14	0.3	0
Meat, Poultry, Fish												
Beef, 3 ounces, without bone, cooked												
Chuck	51	265	22	19	0	9	2.6	0	0.04	0.17	3.5	0
Hamburger	47	315	19	26	0	8	2.4	0	0.07	0.16	4.1	0
Sirloin	54	255	20	19	0	9	2.5	0	0.06	0.16	4.1	0
Beef, canned												
Corned beef, medium fat, 3 ounces	59	180	22	10	0	17	3.7	0	0.01	0.20	2.9	0
Corned beef hash, 3 ounces	70	120	12	5	6	22	1.1	Tr.	0.02	0.11	2.4	0
Strained (infant food), 1 ounce	78	30	5	1	0	3	1.2	0	Tr.	0.06	0.9	0
Beef, dried, 2 ounces	48	115	19	4	0	11	2.9	0	0.04	0.18	2.2	0
Beef and vegetable stew, 1 cup	79	250	13	19	17	31	2.6	2,520	0.12	0.15	3.4	15
Chicken, canned, boned, 3 ounces	62	170	25	7	0	12	1.5	0	0.03	0.14	5.4	0
Chile con carne, canned (without beans), ⅓ cup	67	170	9	13	5	32	1.2	130	0.01	0.10	1.9	...
Clams, raw, meat only, 4 ounces	80	90	15	2	4	109	7.9	120	0.11	0.20	1.8	...
Cod, dried, 1 ounce	12	105	23	1	0	14	1.0	0	0.02	0.13	3.1	0
Crab meat, canned or cooked, 3 ounces	77	90	14	2	1	38	0.8	......	0.04	0.05	2.1	...

Flounder, raw, 4 ounces	83	80	17	1	0	69	0.9	......	0.07	0.06	1.9	...
Haddock, fried, 1 fillet (4 by 3 by ½ in.)	67	160	19	6	7	18	0.6	......	0.04	0.09	2.6	...
Halibut, broiled, 1 steak (4 by 3 by ½ in.)	64	230	33	10	0	18	1.0	......	0.08	0.09	13.1	...
Heart, beef, raw, 3 ounces	78	90	14	3	1	8	3.9	30	0.50	0.75	6.6	5
Kidneys, beef, raw, 3 ounces	75	120	13	7	1	8	6.7	980	0.32	2.16	5.5	11
Lamb, leg roast, cooked, 3 ounces	56	230	20	16	0	9	2.6	0	0.12	0.21	4.4	0
Lamb, canned, strained (infant food), 1 ounce	79	30	4	1	0	5	0.7	0	0.01	0.07	1.1	0
Liver, beef, fried, 2 ounces	57	120	13	4	5	5	4.4	30,330	0.15	2.25	8.4	18
Liver, canned, strained (infant food), 1 ounce	78	30	5	1	Tr.	7	2.0	5,440	0.01	0.61	1.8	...
Mackerel, canned, solids and liquid, 3 ounces	66	155	16	9	0	157	1.8	370	0.05	0.18	4.9	...
Oysters, meat only, raw, 1 cup (13-19 medium size oysters, selects)	80	200	24	5	13	226	13.4	770	0.35	0.48	2.8	...
Oyster stew, 1 cup with 6 to 8 oysters	80	245	17	13	14	262	7.0	820	0.21	0.46	1.6	...
Pork loin or chops, cooked, 3 ounces without bone	50	285	20	22	0	9	2.6	0	0.71	0.20	4.3	0
Pork, cured ham, cooked, 3 ounces without bone	39	340	20	28	Tr.	9	2.5	0	0.46	0.18	3.5	0
Pork luncheon meat, canned, spiced, 2 ounces	55	165	8	14	1	5	1.2	0	0.18	0.12	1.6	0
Salmon, canned, pink, 3 ounces	70	120	17	5	0	159 *	0.7	60	0.03	0.16	6.8	0
Sardines, canned in oil, drained solids, 3 ounces	57	180	22	9	1	328	2.3	190	0.01	0.15	4.1	0
Sausage												
Bologna, 1 piece (1 by 1½ in. diam.)	62	465	31	34	8	19	4.6	0	0.37	0.40	5.7	0
Frankfurter, 1 cooked	62	125	7	10	1	3	0.6	0	0.08	0.09	1.3	0
Pork, bulk, canned, 4 ounces	55	340	17	29	0	10	2.6	0	0.23	0.27	3.4	0
Scallops, raw, 4 ounces	80	90	17	Tr.	4	29	2.0	0	0.05	0.11	1.6	...
Shad, raw, 4 ounces	70	190	21	11	0	...	0.6	......	0.17	0.27	9.6	...
Shrimp, canned, meat only, 3 ounces	66	110	23	1	...	98	2.6	50	0.01	0.03	1.9	0

* If bones are discarded, calcium content would be much lower. Bones equal about 2 per cent of total contents of can.

Table 1. Nutrients in household quantities of foods—*Continued*

Food and approximate measure or common weight	Water, %	Food energy, cal.	Protein, gm.	Fat, gm.	Total carbohydrate, gm.	Calcium, mg.	Iron, mg.	Vitamin A value, IU	Thiamine, mg.	Riboflavin, mg.	Niacin value, mg.	Ascorbic acid, mg.
Soups, canned, ready-to-serve												
Beef, 1 cup	91	100	6	4	11	15	0.5	......	....	....	....	...
Chicken, 1 cup	94	75	4	2	10	20	0.5	......	0.02	0.12	1.5	...
Chicken, strained (infant food), 1 ounce	87	15	1	1	2	11	0.1	70	Tr.	0.03	0.1	Tr.
Clam chowder, 1 cup	91	85	5	2	12	36	3.6	......	....	....	....	...
Tongue, beef, raw, 4 ounces	68	235	19	17	Tr.	10	3.2	0	0.14	0.33	5.7	0
Tuna fish, drained solids, 3 ounces	60	170	25	7	0	7	1.2	70	0.04	0.10	10.9	0
Veal cutlet, cooked, 3 ounces without bone	60	185	24	9	0	10	3.0	0	0.07 *	0.24 *	5.2 *	0
Mature Beans and Peas; Nuts												
Almonds, shelled, unblanched, 1 cup	5	850	26	77	28	361	6.2	0	0.35	0.95	6.5	Tr.
Beans, canned or cooked, 1 cup												
Red kidney	76	230	15	1	42	102	4.9	0	0.12	0.12	2.0	0
Navy or other varieties with												
Pork and tomato sauce	72	295	15	5	48	107	4.7	220	0.13	0.09	1.2	7
Pork and molasses	70	325	15	8	50	146	5.5	90	0.13	0.09	1.2	7
Beans, Lima, dry, 1 cup	13	610	38	2	113	124	13.7	0	0.88	0.32	3.6	3
Brazil nuts, shelled, 1 cup	5	905	20	92	15	260	4.8	Tr.	1.21	....	....	...
Coconut, dried, shredded (sweetened), 1 cup	3	345	2	24	33	27	2.2	0	Tr.	Tr.	Tr.	0
Cowpeas, dry, 1 cup	11	685	46	3	123	154	13.0	60	1.84	0.32	4.5	3
Peanuts, roasted, shelled, 1 cup	3	805	39	64	34	107	2.7	0	0.42	0.19	23.3	0
Peanut butter, 1 tablespoon	2	90	4	8	3	12	0.3	0	0.02	0.02	2.6	0
Peas, split, dry, 1 cup	10	690	49	2	123	66	10.2	740	1.53	0.56	6.3	4
Pecans, 1 cup halves	3	750	10	79	14	80	2.6	50	0.77	0.12	1.0	2

Soybeans, dry, 1 cup

Soybeans, dry, 1 cup	7	695	73	38	73	477	16.8	230	2.25	0.65	4.9	Tr.
Walnuts, English, 1 cup halves	3	655	15	64	16	83	2.1	30	0.48	0.13	1.2	3
Vegetables												
Asparagus												
Cooked, 1 cup cut spears	92	35	4	Tr.	6	33	1.8	1,820	0.23	0.30	2.1	40
Canned green, 6 spears, medium size	92	20	2	Tr.	3	18	1.8	770	0.06	0.08	0.9	17
Canned bleached, 6 spears, medium size	92	20	2	Tr.	3	15	1.0	70	0.05	0.07	0.8	17
Beans, Lima, immature, cooked, 1 cup	75	150	8	1	29	46	2.7	460	0.22	0.14	1.8	24
Beans, snap, green, cooked, 1 cup	92	25	2	Tr.	6	45	0.9	830	0.09	0.12	0.6	18
Beets, cooked, diced, 1 cup	88	70	2	Tr.	16	35	1.2	30	0.03	0.07	0.5	11
Broccoli, cooked, flower stalks, 1 cup	90	45	5	Tr.	8	195	2.0	5,100	0.10	0.22	1.2	111
Brussels sprouts, cooked, 1 cup	85	60	6	1	12	44	1.7	520	0.05	0.16	0.6	61
Cabbage, 1 cup												
Raw, shredded	92	25	1	Tr.	5	46	0.5	80	0.06	0.05	0.3	50
Cooked	92	40	2	Tr.	9	78	0.8	150	0.08	0.08	0.5	53
Carrots												
Raw, grated, 1 cup	88	45	1	Tr.	10	43	0.9	13,200	0.06	0.06	0.7	7
Cooked, diced, 1 cup	91	45	1	1	9	38	0.9	18,130	0.07	0.07	0.7	6
Canned, strained (infant food), 1 ounce	92	10	Tr.	0	2	7	0.2	2,530	0.01	0.01	0.1	1
Cauliflower, cooked, flower buds, 1 cup	92	30	3	Tr.	6	26	1.3	110	0.07	0.10	0.6	34
Celery, 1 cup												
Raw, diced	94	20	1	Tr.	4	50	0.5	0	0.05	0.04	0.4	7
Cooked, diced	94	25	2	Tr.	5	65	0.6	0	0.05	0.04	0.4	6
Collards, cooked, 1 cup	87	75	7	1	14	473	3.0	14,500	0.15	0.46	3.2	84
Corn, sweet												
Cooked, 1 ear (5 in. long)	75	85	3	1	20	5	0.6	390 †	0.11	0.10	1.4	8
Canned, solids and liquid, 1 cup	80	170	5	1	41	10	1.3	520 †	0.07	0.13	2.4	14
Cowpeas, immature seed, cooked, 1 cup	75	150	11	1	25	59	4.0	620	0.46	0.13	1.3	32

* Data assume cut to be prepared by braising or pot roasting. Use of proportionate quantity of drippings would add approximately 50 per cent more thiamine and niacin and 25 per cent more riboflavin.

† Vitamin A based on yellow corn; white corn contains only a trace.

Table 1. Nutrients in household quantities of foods—*Continued*

Food and approximate measure or common weight	Water, %	Food energy, cal.	Protein, gm.	Fat, gm.	Total carbohydrate, gm.	Calcium, mg.	Iron, mg.	Vitamin A value, IU	Thiamine, mg.	Riboflavin, mg.	Niacin value, mg.	Ascorbic acid, mg.
Cucumbers, raw, 6 slices (1/8 in. thick, center section)	96	5	Tr.	0	1	5	0.2*	0*	0.02	0.02	0.1	4
Dandelion greens, cooked, 1 cup	86	80	5	1	16	337	5.6	27,310	0.23	0.22	1.3	29
Endive, raw, 1 pound	93	90	7	1	18	359	7.7	13,600	0.30	0.53	1.8	49
Kale, cooked, 1 cup	87	45	4	1	8	248	2.4	9,220	0.08	0.25	1.9	56
Lettuce, headed, raw, 2 large or 4 small leaves	95	5	1	Tr.	1	11	0.2	270	0.02	0.04	0.1	4
Mushrooms, canned, solids and liquid, 1 cup	93	30	3	Tr.	9	17	2.0	0	0.04	0.60	4.8	...
Mustard greens, cooked, 1 cup	92	30	3	Tr.	6	308	4.1	10,050	0.08	0.25	1.0	63
Okra, cooked, 8 pods (3 in. long, 5/8 in. diam.)	90	30	2	Tr.	6	70	0.6	630	0.05	0.05	0.7	17
Onions, raw												
Mature, 1 onion (2½-in. diam.)	88	50	2	Tr.	11	35	0.6	60	0.04	0.04	0.2	10
Young green, 6 small onions without tops	88	25	Tr.	Tr.	5	68	0.4	30	0.02	0.02	0.1	12
Parsnips, cooked, 1 cup	84	95	2	1	22	88	1.1	0	0.09	0.16	0.3	19
Peas, green												
Cooked, 1 cup	82	110	8	1	19	35	3.0	1,150	0.40	0.22	3.7	24
Canned, strained (infant food), 1 ounce	87	15	1	Tr.	2	5	0.4	180	0.03	0.02	0.3	2
Peppers, green, raw, 1 medium	92	15	1	Tr.	4	7	0.3	400	0.02	0.04	0.2	77
Potatoes												
Baked, 1 medium (2½-in. diam.)	74	95	2	Tr.	22	13	0.8	20	0.11	0.05	1.4	17
Boiled in skin, 1 medium (2½-in. diam.)	78	120	3	Tr.	27	16	1.0	30	0.14	0.06	1.6	22
Boiled after peeling, 1 medium (2½-in. diam.)	78	105	3	Tr.	24	14	0.9	20	0.12	0.04	1.3	17
French-fried, 8 pieces (2 by ½ by ½ in.)	20	155	2	8	21	12	0.8	20	0.07	0.04	1.3	11
Potato chips, 10 medium (2-in. diam.)	3	110	1	7	10	6	0.4	10	0.04	0.02	0.6	2
Pumpkin, canned, 1 cup	90	75	2	1	18	46	1.6	7,750	0.04	0.14	1.2	...

Radishes, raw, 4 small	94	5	Tr.	0	1	7	0.2	10	0.01	Tr.	0.1	5
Rutabagas, cooked, cubed or sliced, 1 cup	91	50	1	Tr.	12	85	0.6	540	0.08	0.11	1.1	33
Sauerkraut, canned, drained solids, 1 cup	91	30	2	Tr.	7	54	0.8	60	0.05	0.10	0.2	24
Soybean sprouts, raw, 1 cup	86	50	7	1	6	51	1.1	190	0.24	0.21	0.9	14
Spinach												
Cooked, 1 cup	91	45	6	1	6	223 †	3.6	21,200	0.14	0.36	1.1	54
Canned, strained (infant food), 1 ounce	94	5	1	Tr.	1	22 †	0.4	1,190	0.01	0.03	0.1	2
Squash												
Summer, cooked, diced, 1 cup	95	35	1	Tr.	8	32	0.8	550	0.08	0.15	1.3	23
Winter, baked, mashed, 1 cup	86	95	4	1	23	49	1.6	12,690	0.10	0.31	1.2	14
Winter, canned, strained (infant food), 1 ounce	91	10	Tr.	Tr.	2	9	0.1	560	0.01	0.02	0.1	1
Sweet potatoes, peeled, 1 sweet potato												
Baked (5 by 2-in.)	61	185	3	1	41	44	1.1	11,410 ‡	0.12	0.08	0.9	28
Boiled (5 by 2½ in.)	69	250	4	1	57	62	1.4	15,780 ‡	0.18	0.11	1.3	41
Tomatoes												
Raw, 1 medium (2 by 2½ in.)	94	30	2	Tr.	6	16	0.9	1,640	0.08	0.06	0.8	35
Canned or cooked, 1 cup	94	45	2	Tr.	9	27	1.5	2,540	0.14	0.08	1.7	40
Tomato juice, canned, 1 cup	94	50	2	Tr.	10	17	1.0	2,540	0.12	0.07	1.8	38
Turnips, cooked, diced, 1 cup	92	40	1	Tr.	9	62	0.8	Tr.	0.06	0.09	0.6	28
Turnip greens, cooked, 1 cup	90	45	4	1	8	376	3.5	15,370	0.09	0.59	1.0	87
Vegetables, mixed, canned, strained (infant food), 1 ounce	90	10	Tr.	0	2	9	0.3	§	0.01	0.01	0.1	1
Fruits												
Apples, raw, 1 medium (2½-in. diam.)	84	75	Tr.	1	20	8	0.4	120	0.05	0.04	0.2	6
Apple juice, fresh or canned, 1 cup	86	125	Tr.	0	34	15	1.2	90	0.05	0.07	Tr.	2

* Based on pared cucumber; unpared contains about 0.6 mg. of iron and 130 IU vitamin A.

† Calcium may not be usable because of presence of oxalic acid.

‡ If very pale varieties only were used, the vitamin A value would be very much lower.

§ Vitamin A value ranges from 270 to 1510 IU per ounce.

Table 1. Nutrients in household quantities of foods—*Continued*

Food and approximate measure or common weight	Water, %	Food energy, cal.	Protein, gm.	Fat, gm.	Total carbohydrate, gm.	Calcium, mg.	Iron, mg.	Vitamin A value, IU	Thiamine, mg.	Riboflavin, mg.	Niacin value, mg.	Ascorbic acid, mg.
Apple betty, 1 cup	64	345	4	7	70	34	0.2	370	0.13	0.09	1.1	3
Applesauce, canned, sweetened, 1 cup	80	185	1	Tr.	50	10	1.0	80	0.05	0.03	0.1	3
Apricots												
Raw, 3 apricots	85	55	1	Tr.	14	17	0.5	2990	0.03	0.05	0.9	7
Canned in sirup, 4 medium halves and 2 tablespoons sirup	77	95	1	Tr.	26	12	0.4	1650	0.02	0.03	0.4	5
Canned, strained (infant food), 1 ounce	83	15	Tr.	Tr.	4	6	0.3	480	0.01	0.01	0.1	1
Dried, cooked, unsweetened, fruit and liquid, 1 cup	75	240	5	Tr.	62	80	4.6	6900	0.01	0.14	2.8	9
Avocados, raw, ½ peeled fruit (3½ by 3¼ in.)	65	280	2	30	6	11	0.7	330	0.07	0.15	1.3	18
Bananas, raw, 1 medium (6 by 1½ in.)	75	90	1	Tr.	23	8	0.6	430	0.04	0.05	0.7	10
Blackberries, raw, 1 cup	85	80	2	1	18	46	1.3	280	0.05	0.06	0.5	30
Blueberries, raw, 1 cup	83	85	1	1	21	22	1.1	400	0.04	0.03	0.4	23
Cantaloupes, raw, ½ melon (5 in. diam.)	94	35	1	Tr.	8	31	0.7	6190 *	0.09	0.07	0.9	59
Cherries, 1 cup pitted												
Raw	83	65	1	1	16	19	0.4	710	0.05	0.06	0.4	9
Canned red sour	87	120	2	1	30	28	0.8	1840	0.07	0.04	0.4	14
Cranberry sauce, sweetened, 1 cup	48	550	Tr.	1	142	22	0.8	80	0.06	0.06	0.3	5
Dates, "fresh" and dried, pitted and cut, 1 cup	20	505	4	1	134	128	3.7	100	0.16	0.17	3.9	0
Figs, raw, 3 small (1½-in. diam.)	78	90	2	Tr.	22	62	0.7	90	0.06	0.06	0.6	2
Figs, dried, 1 large (2 by 1 in.)	24	55	1	Tr.	14	39	0.6	20	0.03	0.02	0.4	0
Fruit cocktail, canned, solids and liquid, 1 cup	81	180	1	1	48	23	1.0	410	0.03	0.03	0.9	5
Grapefruit, raw, 1 cup sections	89	75	1	Tr.	20	43	0.4	20	0.07	0.04	0.4	78

Grapefruit juice												
Canned, unsweetened, 1 cup	89	90	1	Tr.	24	20	0.7	20	0.07	0.04	0.4	85
Frozen concentrate, 6-ounce can	58	295	4	1	77	63	2.4	60	0.24	0.13	1.4	272
Grapes, 1 cup												
American type (slip skin)	82	85	2	2	18	20	0.7	90	0.07	0.05	0.3	5
European type (adherent skin)	82	100	1	1	26	26	0.9	120	0.09	0.06	0.4	6
Grape juice, bottled, 1 cup	81	170	1	0	46	25	0.8	......	0.09	0.12	0.6	Tr.
Lemon juice, fresh, 1 cup	91	60	1	Tr.	19	34	0.2	0	0.11	0.01	0.3	122
Lime juice, fresh, 1 cup	91	60	1	0	20	34	0.2	0	0.11	0.01	0.3	65
Oranges, 1 medium (3-in. diam.)	87	70	1	Tr.	17	51	0.6	290	0.12	0.04	0.4	77
Orange juice												
Fresh, 1 cup	88	110	2	Tr.	27	47	0.5	460	0.19	0.06	0.6	122
Canned, unsweetened, 1 cup	88	110	2	Tr.	27	25	0.7	240	0.17	0.04	0.6	103
Frozen concentrate, 6-ounce can	58	300	5	1	75	69	2.0	670	0.48	0.11	1.5	285
Papayas, raw, cubed, 1 cup	89	70	1	Tr.	18	36	0.5	3190	0.06	0.07	0.5	102
Peaches												
Raw, 1 medium (2½ by 2-in. diam.)	87	45	1	Tr.	12	8	0.6	880	0.02	0.05	0.9	8
Canned in sirup, solids and liquid, 1 cup	81	175	1	Tr.	47	13	1.0	1160	0.02	0.05	1.8	11
Canned, strained (infant food), 1 ounce	83	15	Tr.	Tr.	4	2	0.3	180	0.01	0.01	0.2	1
Dried, cooked, unsweetened, 1 cup (10-12 halves and 6 tablespoons liquid)	76	225	2	1	59	38	5.9	2750	0.01	0.16	4.3	11
Pears												
Raw, 1 pear (3 by 2½-in. diam.)	83	95	1	1	24	20	0.5	30	0.03	0.06	0.2	6
Canned in sirup, 2 medium-size halves and 2 tablespoons sirup	81	80	Tr.	Tr.	22	9	0.2	Tr.	0.01	0.02	0.2	2
Canned, strained (infant food), 1 ounce	86	15	Tr.	Tr.	4	3	0.1	10	Tr.	0.01	0.1	Tr.
Persimmons, Japanese, raw, seedless kind, 1 persimmon (2¼-in. diam.)	78	95	1	Tr.	24	7	0.4	3270	0.06	0.05	Tr.	13

* Vitamin A based on deeply colored yellow varieties.

Table 1. Nutrients in household quantities of foods—*Continued*

Food and approximate measure or common weight	Water, %	Food energy, cal.	Protein, gm.	Fat gm.	Total carbohydrate, gm.	Calcium, mg.	Iron, mg.	Vitamin A value, IU	Thiamine, mg.	Riboflavin, mg.	Niacin value, mg.	Ascorbic acid, mg.
Pineapple												
Raw, diced, 1 cup	85	75	1	Tr.	19	22	0.4	180	0.12	0.04	0.3	33
Canned in sirup, 2 small or 1 large slice and 2 tablespoons juice	78	95	Tr.	Tr.	26	35	0.7	100	0.09	0.02	0.2	11
Pineapple juice, canned, 1 cup	86	120	1	Tr.	32	37	1.2	200	0.13	0.04	0.4	22
Plums, raw, 1 plum (2-in. diam.)	86	30	Tr.	Tr.	7	10	0.3	200	0.04	0.02	0.3	3
Prunes, cooked, unsweetened, 1 cup (16–18 prunes and 1/3 cup liquid)	65	310	3	1	82	62	4.5	2210	0.07	0.20	2.0	2
Prune juice, canned, 1 cup	80	170	1	0	46	60	4.3	......	0.07	0.19	1.0	2
Raisins, dried, 1 cup	24	430	4	1	114	125	5.3	80	0.24	0.13	0.8	Tr.
Raspberries, red, raw, 1 cup	84	70	1	Tr.	17	49	1.1	160	0.03	0.08	0.4	29
Rhubarb, cooked with sugar, 1 cup	63	385	1	Tr.	98	112 *	1.1	70	0.02	....	0.2	17
Strawberries												
Raw, 1 cup	90	55	1	1	12	42	1.2	90	0.04	0.10	0.4	89
Frozen, 3 ounces	72	90	1	Tr.	23	19	0.5	30	0.02	0.04	0.2	35
Tangerines, 1 medium (2½-in. diam.)	87	35	1	Tr.	9	27	0.3	340	0.06	0.02	0.2	25
Tangerine juice, canned, 1 cup	89	95	2	1	23	47	0.5	1040	0.15	0.06	0.6	64
Watermelons, ½ slice (¾ by 10 in.)	92	45	1	Tr.	11	11	0.3	950	0.08	0.08	0.3	10
Grain Products												
Barley, pearled, light, dry, 1 cup	11	710	17	2	160	32	4.1	0	0.25	0.17	6.3	0
Biscuits, baking powder, enriched flour, 1 biscuit (2½-in. diam.)	27	130	3	4	20	83	0.7	0	0.09	0.08	0.7	0
Bran flakes, 1 cup	4	115	4	1	32	24	2.0	0	0.19	0.09	3.5	0

Breads, 1 slice												
Boston brown, unenriched	44	105	2	1	22	89	1.2	70	0.04	0.06	0.7	0
Rye	35	55	2	Tr.	12	17	0.4	0	0.04	0.02	0.4	0
White, unenriched, 4 per cent nonfat milk solids †	35	65	2	1	12	18	0.1	0	0.01	0.02	0.2	0
White, enriched, 4 per cent nonfat milk solids †	35	65	2	1	12	18	0.4 ‡	0	0.06 ‡	0.04 ‡	0.5 ‡	0
White, enriched, 6 per cent nonfat milk solids	34	65	2	1	12	21	0.4 ‡	0	0.06 ‡	0.04 ‡	0.5 ‡	0
Whole wheat	37	55	2	1	11	22	0.5	0	0.07	0.03	0.7	0
Cakes												
Angel food, 2-in. sector (1/12 of cake, 8-in. diam.)	32	110	3	Tr.	23	2	0.1	0	Tr.	0.05	0.1	0
Doughnuts, cake-type, 1 doughnut	19	135	2	7	17	23	0.2	40	0.05	0.04	0.4	0
Foundation, 1 square (3 by 2 by 1¾ in.)	25	230	4	8	36	82	0.3	100 §	0.02	0.05	0.2	0
Foundation, plain icing, 2-in. sector, layer cake (1/16 of cake, 10-in. diam.)	24	410	6	11	72	121	0.5	150 §	0.03	0.08	0.2	0
Fruit cake, dark, 1 piece (2 by 2 by ½ in.)	23	105	2	4	17	29	0.8	50 ‖	0.04	0.04	0.3	0
Gingerbread, 1 piece (2 by 2 by 2 in.)	30	180	2	7	28	63	1.4	50	0.02	0.05	0.6	0
Plain cake and cupcakes, 1 cupcake (2¾ in. diam.)	27	130	3	3	23	62	0.2	50 ¶	0.01	0.03	0.1	0
Sponge, 2-in. sector (1/12 of cake, 8-in. diam.)	32	115	3	2	22	11	0.6	210	0.02	0.06	0.1	0
Cereal foods, dry, precooked (infant food), 1 ounce	6	105	4	1	21	185	9.6	0	0.34	0.13	1.4 **	0

* Calcium may not be usable because of presence of oxalic acid.

† When the amount of nonfat milk solids in commercial bread is unknown, use bread with 4 per cent nonfat milk solids.

‡ Iron, thiamine, riboflavin, and niacin are based on the minimum levels of enrichment specified in the standards of identity of breads proposed by the Federal Security Agency and published in the Federal Register, August 3, 1943.

§ If fat used is butter or fortified margarine, the vitamin A value would be 350 IU per square, and 520 IU per 2-inch sector, iced.

‖ If fat used is butter or fortified margarine, the vitamin A value would be 120 IU.

¶ If fat used is butter or fortified margarine, the vitamin A value would be 150 IU per cupcake.

** Based on products ranging from 0.7 to 1.9 mg. per ounce. The niacin value of some products is as high as 6.5 mg.

Table 1. Nutrients in household quantities of foods—*Continued*

Food and approximate measure or common weight	Water	Food energy, cal	Protein, gm.	Fat, gm.	Total carbohydrate, gm.	Calcium, mg.	Iron, mg.	Vitamin A value, IU	Thiamine, mg.	Riboflavin, mg.	Niacin value, mg.	Ascorbic acid, mg.
Cookies, plain and assorted, 1 3-in. cooky	3	110	2	3	19	6	0.2	0	0.01	0.01	0.1	0
Corn bread or muffins made with enriched, degermed corn meal, 1 muffin (2¾ in. diam.)	49	105	3	2	18	67	0.9	60 *	0.08	0.11	0.6	0
Corn flakes, 1 cup	4	95	2	Tr.	21	3	0.3	0	0.01	0.02	0.4	0
Corn grits, degermed, cooked, 1 cup												
Unenriched	87	120	3	Tr.	27	2	0.2	100 †	0.04	0.01	0.4	0
Enriched	87	120	3	Tr.	27	2	0.7	100 †	0.11	0.08	1.0	0
Crackers												
Graham, 4 small or 2 medium	6	55	1	1	10	3	0.3	0	0.04	0.02	0.2	0
Soda, plain, 2 crackers (2½-in. diam.)	6	45	1	1	8	2	0.1	0	0.01	0.01	0.1	0
Farina, enriched, cooked, 1 cup	89	105	3	Tr.	22	7	0.5	0	0.10	0.07	0.4	0
Macaroni, cooked, 1 cup												
Unenriched	61	210	7	1	42	13	0.8	0	0.03	0.02	0.7	0
Enriched	61	210	7	1	42	13	1.5	0	0.24	0.15	2.0	0
Muffins, made with enriched flour, 1 muffin (2¾ in. diam.)	37	135	4	4	20	99	0.8	50	0.09	0.10	0.7	0
Noodles, containing egg, unenriched, cooked, 1 cup	84	105	4	1	20	6	0.6	60	0.05	0.03	0.6	0
Oatmeal or rolled oats												
Cooked, 1 cup	85	150	5	3	26	21	1.7	0	0.22	0.05	0.4	0
Precooked (infant food), dry, 1 ounce	7	105	4	1	19	225	8.9	0	0.36	0.10	0.7 ‡	0
Pancakes, baked, wheat, with enriched flour, 1 cake (4-in. diam.)	55	60	2	2	7	43	0.4	50	0.05	0.06	0.3	Tr.

Pies, 4-in. sector (9-in. diam.)												
Apple	48	330	3	13	53	9	0.5	220	0.04	0.02	0.3	1
Custard	59	265	7	11	34	162	1.6	290	0.07	0.21	0.4	0
Lemon meringue	47	300	4	12	45	24	0.6	210	0.04	0.10	0.2	1
Mince	43	340	3	9	62	22	3.0	10	0.09	0.05	0.5	1
Pumpkin	59	265	5	12	34	70	1.0	2480	0.04	0.15	0.4	0
Pretzels, 5 small sticks	8	20	Tr.	Tr.	4	1	0	0	Tr.	Tr.	Tr.	0
Rice, cooked, 1 cup												
Converted	72	205	4	Tr.	45	14	0.5	0	0.10	0.02	1.9	0
White or milled	71	200	4	Tr.	44	13	0.5	0	0.02	0.01	0.7	0
Rice, puffed, 1 cup	4	55	1	Tr.	12	3	0.3	0	0.01	0.01	0.1	0
Rolls, plain, enriched, 1 roll (12 per pound)	29	120	3	2	21	21	0.7 §	0	0.09 §	0.06 §	0.8 §	0
Spaghetti, unenriched, cooked, 1 cup	61	220	7	1	44	13	0.9	0	0.03	0.02	0.7	0
Waffles, baked, with enriched flour, 1 waffle (4½ by 5⅝ by ½ in.)	40	215	7	8	28	144	1.4	270	0.14	0.20	1.0	0
Wheat flours												
Whole, 1 cup stirred	12	400	16	2	85	49	4.0	0	0.66	0.14	5.2	0
All-purpose or family flour:												
Unenriched, 1 cup sifted	12	400	12	1	84	18	0.9	0	0.07	0.05	1.0	0
Enriched, 1 cup sifted	12	400	12	1	84	18	3.2 ‖	0	0.48 ‖	0.29 ‖	3.8 ‖	0
Wheat germ, 1 cup stirred	11	245	17	7	34	57	5.5	0	1.39	0.54	3.1	0
Wheat, shredded, 1 large biscuit, 1 ounce	6	100	3	1	23	13	1.0	0	0.06	0.03	1.3	0

* Based on recipe using white corn meal; if yellow corn meal is used, vitamin A value is 120 IU.

† Vitamin A based on yellow corn grits; white corn grits contain only a trace.

‡ Based on products ranging from 0.4 to 1.2 mg. per ounce of cereal. The niacin value of some products is as high as 6.5 mg. per ounce.

§ Iron, thiamine, riboflavin, and niacin are based on the minimum levels of enrichment specified in the standards of identity of breads proposed by the Federal Security Agency and published in the Federal Register, August 3, 1943.

‖ Iron, thiamine, riboflavin, and niacin are based on the minimum levels of enrichment specified in the standards of identity promulgated under the Food, Drug, and Cosmetic Act.

Table 1. Nutrients in household quantities of foods—*Continued*

Food and approximate measure or common weight	Water, %	Food energy, cal.	Protein, gm.	Fat, gm.	Total carbohydrate, gm.	Calcium, mg.	Iron, mg.	Vitamin A value, IU	Thiamine, mg.	Riboflavin, mg.	Niacin value, mg.	Ascorbic acid, mg.
Sugars, Sweets												
Candy, 1 ounce												
Caramels	7	120	1	3	22	36	0.7	50	0.01	0.04	Tr.	Tr.
Chocolate, sweetened, milk	1	145	2	9	16	61	0.6	40	0.03	0.11	0.2	0
Fudge, plain	5	115	Tr.	3	23	14 *	0.1	60	Tr.	0.02	Tr.	Tr.
Hard	1	110	0	0	28	0	0	0	0	0	0	0
Marshmallows	15	90	1	0	23	0	0	0	0	0	0	0
Chocolate sirup, 1 tablespoon	39	40	Tr.	Tr.	11	3 †	0.3	......	....	....	....	...
Honey, strained or extracted, 1 tablespoon	20	60	Tr.	0	17	1	0.2	0	Tr.	0.01	Tr.	1
Jams, marmalades, preserves, 1 tablespoon	28	55	Tr.	Tr.	14	2	0.1	Tr.	Tr.	Tr.	Tr.	1
Molasses, cane, 1 tablespoon												
Light	24	50	..	...	13 ‡	33	0.9	......	0.01	0.01	Tr.	...
Blackstrap	24	45	..	...	11 ‡	116	2.3	......	0.02	0.04	0.3	...
Sirup, table blends, 1 tablespoon	25	55	0	0	15	9	0.8	0	0	Tr.	Tr.	0
Sugar, 1 tablespoon												
Granulated, cane or beet	Tr.	50	0	0	12	...	....	0	0	0	0	0
Brown	3	50	0	0	13	10 §	0.4	0	0	0	0	0
Miscellaneous												
Beverages, carbonated, kola type, 1 cup	88	105	..	...	28	...	....	......	....	....	....	...
Bouillon cubes, 1 cube	5	2	Tr.	Tr.	0	...	....	......	....	0.07	1.0	0
Chocolate, unsweetened, 1 ounce	2	140	2	15	8	28 †	1.2	20	0.01	0.06	0.3	0
Gelatin dessert, plain, ready-to-serve, 1 cup	83	155	4	0	36	0	0	0	0	0	0	0

Olives, pickled "mammoth" size, 10 olives												
Green	75	70	1	7	2	48	0.9	160	Tr.	....	....	...
Ripe, Mission variety	72	105	1	12	1	48	0.9	40	Tr.	Tr.	....	...
Pickles												
Dill, cucumber, 1 large (4 in. long)	93	15	1	Tr.	3	34	1.6	420	Tr.	0.09	0.1	8
Sweet, cucumber or mixed, 1 pickle (2¾ in. long)	70	20	Tr.	Tr.	5	3	0.3	20	0	Tr.	Tr.	1
Sherbet, ‖ ½ cup	68	120	1	0	29	48	0	0	0.02	0.07	0	0
Vinegar, 1 tablespoon	..	2	0	...	1	1	0.1	......	....	....	....	...
White sauce, medium, 1 cup	73	430	11	33	23	305	0.3	1350	0.09	0.41	0.3	1
Yeast												
Compressed, baker's, 1 ounce	71	25	3	Tr.	3	7	1.4	0	0.13	0.59	8.0	0
Dried brewer's, 1 tablespoon	7	20	3	Tr.	3	8	1.5	0	0.78	0.44	2.9	0

* The calcium contributed by chocolate may not be usable because of presence of oxalic acid; in that case the value would be 11 mg. per ounce.

† Calcium may not be usable because of presence of oxalic acid.

‡ Total sugars only.

§ Calcium is based on dark brown sugar; value would be lower for light brown sugar.

‖ Based on 6.8 pounds to the gallon, factory packed.

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